THE OCTOBER SCIENTIFIC MONTHLY

Edited by

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NEW BOOKS OF SCIENTIFIC INTEREST

This Physical World. C. C. CLARK, C. A. JOHNSON and L. M. COCKADAY. Illustrated. x + 528 pp. $3.25. 1941. McGraw-Hill.

The object of this text is to present a logical and connected story of the physical world for college students. Particular stress is placed on branches of science which man has employed in the progress of civilization.

The Scientific Photographer. A. S. C. LAWRENCE. Illustrated. x + 180 pp. $3.75. July, 1941. Macmillan.

A book on the theory and practise of photography with chapters on: Bases of Photography, Lens and the Image, Mechanism of the Camera, Color Photography, Making a Picture, Developing and Printing, Some Scientific Applications, Formulae for Solutions.

Principles of General Chemistry. S. P. BRINKLEY. 3rd edition. Illustrated. x + 703 pp. $4.00. August, 1941. Macmillan.

This text is intended to meet the requirements of the general college course for students who have had a preparatory course in chemistry. Emphasis is placed on the principles of the science, but industrial applications and processes are included.

Out of the Test Tube. H. N. HOLMES. 3rd edition. Illustrated. 305 pp. $3.00. September, 1941. Emerson.

Written for the layman, this book is intended to instill an appreciation of chemical methods. Beginning with the earliest pioneers, the book goes into the story of the modern laboratory and its importance to-day, including a new chapter on strategic materials.

Papers of Wade Hampton Frost, M.D. K. F. MAXCY, Editor. Illustrated. viii + 619 pp. $3.00. Commonwealth Fund.

Twenty papers of this epidemiologist have been brought together for use as a reference and to show the evolution of epidemiology from a descriptive to an analytic science. A twenty-page biography of the late Dr. Frost is included.

The West Highlands and the Hebrides. A. HARKER. Illustrated. xxiii + 127 pp. $2.00. July, 1941. Cambridge (Macmillan).

This is a geologists' guide for amateurs, having the hills of Sky and the small isles of Inverness-shire as its subjects. Its aim is to interpret the geology and scenery and to arouse in the traveller the inquiring spirit of the author.

The Soils That Support Us. C. E. KELLOGG. Illustrated. xi + 370 pp. $3.50. August, 1941. Macmillan.

This book is intended for those who want to know about the nature, use and conservation of soils. The relationship of soils to the men who use them is stressed. The physics, chemistry, geology and biology of soils are explained without technicalities.

The Body Functions. R. W. GERARD. Illustrated. xiii + 289 pp. $2.25. August, 1941. Wiley.

Part I of this text-book on physiology deals with the balance present between the parts and processes of the human organs; Part II emphasizes the particular ways in which certain living things have solved the general problems which confront all, and the essential physiological similarities within the classes of animals.

Personal Hygiene Applied. J. F. WILLIAMS. 7th edition. Illustrated. xvi + 529 pp. $2.50. 1941. Saunders.

A text-book for college students, placing emphasis on the mental and social, as well as upon the physical aspects of health. Chapters on the meaning of health in terms of life are followed by a systematic treatment of hygiene.

Commercial Fertilizers. G. H. COLLINGS. 3rd edition. Illustrated. xii + 480 pp. 1941. Blakiston.

A text-book on commercial fertilizers for agricultural college use, considering the origin, nature, manufacture of the various fertilizers and the principles underlying their use. The author has incorporated recent research findings and data into the various chapters.

Aztecs of Mexico. G. C. VAILLANT. Illustrated. xxii + 340 pp. $4.00. August, 1941. Doubleday, Doran.

This is a history of the Aztec Indians of the Valley of Mexico, telling of the origin, rise and fall of that great civilization. It draws on contemporary observations of the conquering Spaniards and Aztecs themselves as well as upon reconstructed data.

The Road of a Naturalist. D. C. PEATTIE. Illustrated. viii + 315 pp. $3.00. 1941. Houghton Mifflin.

This is the autobiography of an author-naturalist, which shows him to have some of the characteristics of a philosopher, scientist and poet. Interspersed with biography, are impressionistic descriptions of the West—its landscape, flowers and wild life.

Elementary Logic. W. V. O. QUINE. vi + 170 pp. $2.25. 1941. Ginn.

The purpose of this book on modern logic is to give a better understanding of the basic logical constructions and reasonings involved in ordinary discourse. Nearly half the book has been devoted to analyzing verbal idioms. Instead of subtle techniques, wide-scale analyses are employed.

The Second Yearbook of Research and Statistical Methodology. O. K. BUROS, editor. xx + 383 pp. 1941. Gryphon.

This book consists of 1,652 review excerpts of books on statistical theory in all fields, taken from 283 journals. Its purpose is to acquaint students and teachers with revolutionary changes in statistical analysis in the last twenty years.

THE SCIENTIFIC MONTHLY

OCTOBER, 1941

VITAMIN RESTORATION OF FOODS AS VIEWED BY THE PHYSICIAN

By Dr. RUSSELL M. WILDER

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THE idea of supplementing foods with dietary essentials had its beginning in 1855 when Kostl suggested in Europe the use of natural sea salt or of salt to which had been added potassium iodide. The first use of iodized salt in the United States was begun at the instigation of a Committee of the Medical Association of the State of Michigan. Later iodized salt was accorded "acceptance" by the Council—then the Committee—of Foods and Nutrition of the American Medical Association, and since taking that action that Council has considered favorably addition of vitamin D to milk and canned milk, addition of vitamin A to margarine and of vitamins of the B complex, as well as certain minerals, such as iron and calcium, to wheat flour.

In May, 1939, after much study and discussion, the Council on Foods and Nutrition passed resolutions encouraging, with qualifications, the adding of minerals and vitamins to certain foods in order to restore to them amounts of these substances contained in natural foods. The first qualification was that the addition of only such vitamins and minerals as are in the interest of public health shall be approved, and that the additions shall be made only to the principal human foods in which they naturally occur. Even in these cases the foods after the additions shall not contain more of the vitamins and minerals than they do in their natural states, with the following exceptions: (a) vitamin D may be added to milk up to, but not to exceed, 400 units per quart. (b) vitamin A may be added to substitutes for butter up to, but not to exceed, the amount in butter with high natural content of this vitamin. In both cases if the vitamin added is obtained from a natural source there is no objection to its carrying with it one or more other vitamins. (c) Iodine may be added to table salt not to exceed one part of sodium iodide or potassium iodide to 5,000 parts of salt.

In endorsing the principle of restorative "fortification" of processed foods, the council emphasized that every effort should first be directed to retaining in the products the food values of the natural foods from which they were made. If any fortifications are to be permitted, they should be restricted to foods which are suitable vehicles for the minerals and vitamins to be restored. The added substances should mix well and not lose their potency during the usual conditions of storage, and they should be in such form that they will be assimilated by the consumer.

In the interest of public health, improvement of the inexpensive staple foods is primary in importance, and

what is done should be effected at a minimal added cost to the consumer. Otherwise added vitamins or minerals will not reach those who are most in need of them.

The aim in restorative fortification of foods is not to reach some hypothetical goal which has no bearing on the problem of human nutrition. It is to provide dietary essentials which people must get from their foods in order to maintain good health. The restored foods should make it easier for the person unskilled or unversed in nutrition to obtain the vitamins and minerals he ought to get with his food.

The policy enunciated in the resolutions of the council referred in particular to the widely used staples. However, the council has accepted some specialty products, including a number of breakfast foods, to which vitamins or minerals or both have been added where the additions do not exceed those in natural foods of the same class. In addition, it has been the policy of the council to consider and accept foods intended for special dietary purposes in which vitamins or minerals are contained or have been added in amounts exceeding those in common natural foods. In such instances acceptance involves compliance with special requirements as to labeling and advertising not demanded for general purpose foods. The thought underlying acceptance of special purpose foods is that they will be used, in the main, on advice received from physicians. Examples of products of this kind are wheat germ, yeast, grass concentrates and fruit juices or cereal products which have more than "restorative" additions of vitamins. Other examples are special foods which are low in carbohydrates or calories.

The Committee on Food and Nutrition of the National Research Council, which now is advisory to the Coordinator of Health, Welfare and Related Defense Activities, was organized in November, 1940, to provide scientific guidance for the national nutrition program which then was being planned. This committee is made up of physicians, nutritional physiologists and others having special knowledge of nutrition. One of the first matters brought to its attention was the scientific testimony that had been given a short time before at the public hearings on flour conducted by the Food and Drug Administration. The committee endorsed the recommendations made at these hearings by several of its members, and then proceeded to give similar consideration to possibilities for improving the nutritive qualities of bread.

With the approval of the Food and Drug Administration the committee proposed to the millers and bakers that they proceed with the manufacture and distribution of flours and breads which would meet the standards recommended for content of thiamine, nicotinic acid and iron. The suggestion was followed, and since then such products have been on the market under the names "enriched flour" and "enriched bread."

Standards for "enriched flour," as proposed by the Food and Drug Administration, were published in the "Federal Register" for April 1, 1941. As there set forth, they closely followed the recommendations of the Committee on Food and Nutrition of the National Research Council. Riboflavin, however, which by the committee had been made an optional ingredient of flour, with the recommendation, however, that it be considered a requirement as soon as adequate supplies of it became available, was included in the federal proposal among the required ingredients.

In the course of the next twenty-one days, a period which the law provides for filing exceptions to proposals for regulations under the Wheeler-Lea Act, objections filed by the industry included objections to the requirement for ribo-

flavin. The matter then was reviewed by the Food and Drug Administration, and a decision was announced by the administrator in the address of Mr. McNutt at the National Nutrition Conference for Defense on May 26, 1941. He stated that the date for the enforcement of the standards had been pushed ahead to January, 1942, instead of having them effective at the end of ninety days, as is usual. This, it was anticipated, would enable manufacturers of riboflavin to provide the required amounts of this vitamin. However, the industries which had cooperated so completely with the program iniatiated by the Committee on Food and Nutrition were assured that "nothing would be done which would penalize them for events beyond their control." The matter will be reviewed in the fall if necessary.

Further Actions and Opinions

In the meantime, the Committee on Food and Nutrition of the National Research Council, after additional thought and time had been devoted to the general policy involved in modifying foods by additions of vitamins and minerals, had taken two actions. One of these was an expression of policy as follows[1]:

> The broad policy of the Committee on Food and Nutrition of the National Research Council is to assist in securing adequate nutrition for the greatest number of people. In what it has done to date, consideration has been given and in the future such consideration will continue to be given both to the nutritional requirements and to the supply of essential nutrients in all foods. Every effort has been and will be made to supply this demand through natural foods, and the Committee is emphasizing educational and research projects and other forms of assistance designed to develop methods for the fuller and better utilization of natural foods. However, due to emergency conditions which now exist, specific enrichment procedures may need to be recommended. One has already been recommended, namely, enrichment of flour and bread. Others will be considered individually, each on its own merits.

[1] Council on Pharmacy and Chemistry; Council on Foods, *Jour. Am. Med. Asn.*, 113: 680–681, 1939.

The other action taken by the Committee on Food and Nutrition was in the nature of a recommendation to limit the use of the word "enriched." The recommendation is to the effect that the use of the word "enriched" be restricted to wheat flour and breads made with wheat flour, and that it be not applied to breads commonly known by other designations, such as rye bread or peanut flour bread; also that it be not applied to other foods for which appropriate nutritional improvements may later be recommended.

This action was in no sense discriminatory in favor of wheat bread, enriched in accordance with the recommendations of the committee, over rye bread, soybean bread, peanut flour bread or other products consisting of mixtures of wheat flour with other flour. Also it should be emphasized that "enriched" bread, that is, wheat bread may be enriched not only by additions of purified vitamins or high vitamin yeasts, according to the original recommendations of the committee, but also by processes of milling, whereby the required nutrients, thiamine, nicotinic acid and iron, are retained. To make this point clear the committee now has recommended that breads, such as rye bread, soy bread and other cereal products which meet the standards for thiamine, nicotinic acid and iron, be permitted to indicate that fact on the labeling and in advertising. The suggestion was made, for instance, that in the case of rye bread the label be "rye bread," and under the name the statement, providing the claim can be made truthfully: "this bread meets the standards for enriched bread." At the discrimination of the baker the statement might even be applied to the advertising and labeling of whole wheat bread. Those "in the know" about whole wheat bread would consider such a designation superfluous.

An additional recommendation of the committee was that bakery products other than bread, as bread is defined in Paragraph 2 of Section 3 on page 7 of

the publication named "Service and Regulatory Announcements, Food and Drug Administration." Revision 5, November, 1936, should not be named "enriched," on the ground that cakes, pies, doughnuts and similar products either contain insignificant and highly variable amounts of flour, or if made with "enriched" flour would be subjected to influences in baking destructive to the thiamine contained in the "enriched" flour. However, the committee recommended that no objection be taken to a baker who wishes to display a general statement indicating that the wheat flour used in the manufacture of his products is "enriched" flour.

The decision of the committee to advise that the word "enriched" be not applied to other foods for which appropriate nutritional improvements may later be recommended was based on the opinion that a more appropriate designation than "enriched" could be found for such products.

It is not possible to state at present whether these later recommendations of the committee will be acceptable to the administrative branches of the government. However, administrative regulation must of necessity wait on public hearings still to be held on bread, rye bread and other breads and on rye flour and other flours than wheat flour. In the meantime, the recommendations of the committee are intended to serve as a guide to procedure.

Additional expression of professional opinion in the matter of fortification of foods is to be found in the proceedings of those sections of the recent National Nutrition Conference for Defense in which the medical aspects of the nutritional problem received attention. Chief of them was Section III, on Public Health and Medical Aspects of Nutrition. It met under the co-chairmanship of Dr. James S. McLester and Dr. Richard Smith.

The principal report of Section III contains an endorsement of the action of the Committee on Food and Nutrition of the National Research Council sponsoring enrichment of flour and bread. The subsection, headed by Dr. Smith, was concerned with the nutrition of pregnant and lactating women and of children. In the special report from this section, Section IIIb, fortification was accepted with some reservation. The statement on the subject reads:

> It is the opinion of this section that all the scientific nutrients can and should be provided through natural foods. Great progress is being made in the proper milling of grains so as to retain their full nutritive value. Pending further developments in this field fortification of flour may be acceptable.

On the basis of these reports and of reports from other sections of the conference, the recommendations to the President, as formulated by Director M. L. Wilson and unanimously adopted at the last general session of the conference, contain an endorsement of the principle of improving the nutritional value of staple food products by addition to them of nutritive elements that have been removed by processes of milling and refining. It was emphasized, however, that the method should be used with discretion and only on the basis of findings by medical and nutritional experts.

Personal opinions. With minor exceptions my own views on the subject of fortification are in harmony with the pronouncements of these various bodies of physicians and scientists. I am strongly of the opinion that a diet of natural foods represents the ideal way to obtain the nutrients required for health. Where I differ at all from some of the nutritionists is in the emphasis to be placed on those vitamins of the vitamin B complex which now are known to be necessary for the satisfactory oxidation of carbohydrate. They include thiamine, riboflavin and nicotinic acid.

It formerly has been taught that the principal shortcomings of American diets are in the contents of vitamin A and calcium. These can be corrected by supplying more green vegetables and milk, and until recently the major emphasis in the teaching of nutritionists has been on obtaining enough green vegetables and enough milk.

Without in any way minimizing the importance of such teaching, it seems to me that equal emphasis must be placed on providing greater allowances of thiamine, and possibly also of nicotinic acid, than either green vegetables or milk will supply. Milk is a good source of riboflavin but not of thiamine, and neither the leafy nor the tuberous vegetable contains much thiamine. Dr. Jolliffe,[2] writing in 1938, was the first to focus American attention on this phase of the nutrition problem. The diet of the American of sixty years ago, when the consumption of flour was almost twice that of to-day and the flour was not refined, contained nearly 1,000 international units of vitamin B_1 (3 milligram of thiamine) per day. "The twentieth century American consumes more fresh fruits, vegetables and dairy products. This gives him in many respects a better balanced diet than the American had before 1880, but the accrual from these foods does not compensate for the deficit . . . of vitamin B_1 resulting from loss (of this vitamin) in the milling of our grain and from the lack (of this vitamin) in our sugar." To obtain the lost 550 international units of vitamin B_1 from vegetables and milk a man would have to consume approximately 1.4 pounds of fruit, as much potatoes, 2 pounds of other vegetables and nearly a quart and a half of milk a day, an obvious impossibility.

In point of fact, the present-day diet of persons with liberal incomes rarely contains more than 330 international units of vitamin B_1 (1 milligram of thiamine), and in families where meat can not be used in reasonably large amounts, the amount of thiamine provided by the diet, as careful surveys have revealed, is less than 330 international units.

Industry and Nutrition

I made a statement to the press some time ago which, widely quoted, has aroused much skepticism and some rather ill-tempered criticism. I want to repeat that statement here in order further to discuss my reason for making it.

I suggested in essence that the low content of thiamine in the diets of urban workers and some of their employers might contribute importantly to the problem of industrial unrest. The suggestion is supported by very good evidence, obtained in the rigidly controlled experiments conducted by my associates, Ray D. Williams and Harold L. Mason, of the Mayo Clinic.[3] I mention this additional work of Williams and Mason because of its direct bearing on the point at issue.

In the studies of Williams and Mason, reported this year to the American Institute of Nutrition, eleven volunteer female subjects were placed, for from four to six months, on a diet adequate in every way except in thiamine. The amount of thiamine contained in the diet represented approximately 22 micrograms for each 100 calories. This is very little less than the thiamine reported for the poor diets of several nutritional surveys that have been reported. The subjects later were given additional thiamine without their knowledge. Several of these women had been under observation for a year or more. They and the others were selected because of special willingness to cooperate, previously satisfactory diets and absence

[2] Norman Jolliffe, *Internat. Clin.*, 4: 46–66, 1938.

[3] R. D. Williams and H. L. Mason, *Proc. of Staff Meets of the Mayo Clinic*, 16: 433–438, July 9, 1941.

of manifest physical or emotional abnormality. After a few weeks on the low thiamine diet all of them became depressed, irritable and quarrelsome. Their meals were attractive in appearance and taste, much more so than the meals routinely provided in the hospital. Their living quarters were pleasant and various diversions were arranged to keep them occupied. In spite of all this it took the greatest tact and diplomacy on the part of the experienced supervising personnel to hold them to the program they previously had agreed to follow. In a few months a "strike" threatened daily, and at the end of six months open rebellion could not be prevented.

Then the thiamine was given, and although the diets were otherwise unchanged and the surroundings remained exactly as they were, the difficulties disappeared and it was possible to continue uninterrupted observations as long as was necessary to obtain the information which the study was designed to provide. This was for periods of from five to seven months. The thiamine was given in very small doses which were increased gradually until the total intake of this vitamin was 2 milligrams a day. After the allowance had reached 1 milligram or more a day all the previous difficulties disappeared. The women then were as willing to work as they had been before the beginning of the study. During the period of restricted intake of thiamine they became disinterested to the point of neglecting their own cleanliness and refusing to make their beds and clean the rooms they occupied. After they obtained thiamine they were quite content to resume the many tasks, such as ward housekeeping, laundry and sewing, that were assigned to them.

An anecdote related by Mr. McNutt at the National Nutrition Conference is one of many that could be cited to illustrate the effect of malnutrition on the psychologic aspects of industrial situations.

> The Tennessee Valley authority went back forty miles behind Norris Dam to the little town of Wilder, a ghost town, a submerged coal town. There several hundred stranded miners' families were barely subsisting, and only the guards at the closed mines ate regularly. Bad actors, vicious, unreliable people, trouble makers, that's what they were; so officials were told. But the officials fortunately were too pigheaded to believe it. They sent a labor representative to Wilder, signed up forty men, put them on regular pay, regular food and hard jobs, and soon these men became some of the best men TVA had.

The importance to industry of the growing knowledge of nutrition is further emphasized by information received from leaders in the field of industrial medicine. In factories to-day, where the most elaborate precautions have been taken to prevent industrial accidents, human errors lead to accidents. They are made by men with training and experience. They almost always seem to be due to inattentiveness and the inattentiveness in turn is attributed to worry. The worried worker, I am told, represents the biggest problem of industrial medicine. Here again inadequate diet, and in particular thiamine deficiency, seem to be contributing importantly. The food of urban workers is notably deficient in many respects. By standards for thiamine based on the Mayo Clinic experiments and now accepted by the Committee on Food and Nutrition of the National Research Council, they are especially deficient in thiamine, and I desire to emphasize the fact that among the first symptoms to develop from lack of sufficient thiamine in the controlled experiments of Williams and Mason were worry, fear, anxiety and inattentiveness.

I do not wish to be understood to mean that thiamine is the only vitamin, lack of which leads to such symptoms as worry, inattentiveness and irritability. It is possible that lack of other vitamins

has similar effects. Nor would I have it supposed that worry, inattentiveness and irritability may not result from many other causes. The main point of my argument is that diets which are inadequate in thiamine have been shown to cause these symptoms.

A section of the National Nutrition Conference for Defense, under the chairmanship of Dr. Frank Boudreau, devoted attention to the nutrition for workers in defense industries. A recommendation from that section reads as follows: "that adequately controlled studies be conducted in selected defense plants to determine the facts concerning the influence of diet on health, working capacity, incidence of accidents, absenteeism and the psychological state, industrial unrest." Workers and employers who cooperate with government or private scientific agencies in carrying on such studies will be performing a major service. Properly controlled investigation can provide the only convincing evidence of the benefits of suitably supplemented diets, and such investigation must be had. In the meantime, in view of the emergency and in the light of experience already accumulated, supplemental feeding in factories is recommended wherever it is found that the diets of defense workers are not fully adequate from the point of view of modern knowledge of nutrition. In England and in individual plants in America where supplemental feeding has been used, efficiency has been increased, accidents have been reduced and the volume of absenteeism has been diminished.

When the question is asked as to what kind of supplemental feeding should be resorted to for factory workers and other groups of persons, we find ourselves in the more contentious field of actual practice. Here I can offer nothing more than bare suggestions. It would seem desirable to avoid the use of purified vitamins as such. Although I have personally seen great benefit from prescribing 1 or 2 milligrams a day of crystalline thiamine to individual patients whose principal deficiency of diet was, I thought, a lack of sufficient thiamine, in most cases even a mixture of all the purified vitamins probably will not suffice for optimal results. Furthermore, such preparations are much too dear for continuous administration. There is fairly good agreement among those considering this problem that vitamin concentrates are preferable, in general, to isolated vitamins. Natural sources of so-called concentrates are yeast, rice polishings, wheat germ, liver and fish liver oils.

The problem of the industrial plant is not unlike one faced daily in hospital practice, and could be solved as physicians have solved it by providing a mixture of fruit or tomato juice, or a bouillon to which are added suitable extracts of yeast or rice polishings and a drop or two of an oil rich in vitamin A. Whatever is used must be appetizing. Also desirable as a supplement to most diets, because of its calcium and excellent protein, is milk, although milk alone, for reasons I have already given, is not enough.

Except for special purposes I question the expediency of resorting to highly fortified processed foods, although such foods should be tried. A number of them have been developed; one has been accepted by the Council on Foods and Nutrition of the American Medical Association. In England the main resort has been to cooked meals containing several of the protective foods. A practical difficulty with such a procedure is costliness and consumption of time.

Fundamental Policy

This brings me back to the question of fundamental policy. In this policy those of us who provided the scientific testimony at the Federal hearings on flour were in disagreement with the legal ad-

visers of the Food and Drug Administration. In our opinion fortification of general purpose foods was undesirable, and we wanted to recommend that additions of vitamins to flour should be related to the vitamins originally present in the wheat from which the flour came. We recognized that wheats differ in content of vitamins, but anticipated no objection to establishing by definition an arbitrary standard of reference. What we aimed at was an improvement in the nutritive values of flour so that persons using the improved product could more easily plan diets that were satisfactory. We indicated that additions of vitamins to general purpose foods, in excess of the amounts present in natural foods of the class, might not be in the interest of the public health, and expressed a desire to place emphasis on this point of view by designating the suggested procedure, "restoration."

The lawyers, however, were of the mind that because wheats varied widely in their content of thiamine and other vitamins, an arbitrary definition for a standard wheat would not hold up in court, that the additions of thiamine and other nutrients to flour were made in fact to increase the consumption of these nutrients by the consumers of the flour; therefore, that the term, "restoration," was inappropriate and some other designation would be necessary. In consequence we got the word "enriched" and no recognition of our basic philosophy.

The decision of the lawyers may prove best from legal angles. From the scientific point of view it confuses and has led to misinterpretation. Our single purpose has been to correct a nutritional environment which by the refining of staple foods has been distorted. We are not prepared to improve on nature. The present nutritional knowledge does not justify the attempt. As physicians with patients whom we have examined and can continue to observe, or even for groups of persons who can be held under some degree of medical supervision, as in the case of workers in industrial plants, we may with propriety prescribe vitamins in doses exceeding those to be obtained from diets of natural foods. But the unlimited prescription of vitamins for the public at large is going further than most physicians, including those of us who testified at the hearings on flour, are prepared at present to go.

It is worthy of note, however, that while the principle of "restoration" was obscured at the hearing on flour, the amounts of thiamine, riboflavin, nicotinic acid and iron to be required in "enriched" flour are essentially those which would have been required had the basis of the decision been restoration and not enrichment. We can take some satisfaction in this outcome. In further considerations of fortification of general purpose foods it will continue to be wise, in my opinion, to be guided by the principle of restoration, or restorative fortification, whereby only so much of a vitamin or mineral is added to any food as will impart to the food, with respect to the substances restored or added, the nutritive values of natural foods of the same class.

SIR CHARLES LYELL'S NUGGETS OF AMERICAN HISTORY

By EMILY EVELETH SNYDER
LITTLE FALLS, NEW YORK

EVERY one is agreed that Charles Darwin brought about a revolution in thinking as far as the biological sciences are concerned. Although his theory of evolution fell far short of completely explaining changes in species during the past ages, yet it did stimulate and direct the study of biology to an inestimable degree. It is a well-known fact that after pondering over the material he collected during the voyage of the *Beagle*, 1831–1836, a book he happened to read gave him a clue to the meaning of this material. That book was Malthus's "Essay on Population," published in 1798. Incidentally this same book influenced Russell Wallace, who, half-way around the earth, worked out a theory of evolution which had a marked similarity to Darwin's.

Besides the book that came to Darwin's attention after he had done his collecting, there was another book, given him to read on the outward passage, which was of greatest importance. This was Lyell's "Principles of Geology," published in 1830, and it made Darwin's outlook very different than it would otherwise have been. A former teacher presented Darwin with the "Principles" and advised him to read it but not to believe it. He read it, but far from disbelieving it, he found evidence everywhere that confirmed Lyell's general thesis that the present condition of the earth's surface is the result of changes which have occurred during long, long periods of time. Furthermore, Lyell believed that these changes have been brought about by the same conditions and agencies that were acting at the moment. His opinion was in opposition to the opinions of those who believed literally in the biblical description of the creation of the earth, and of the catastrophists, and neptunists. The former believed that the earth had experienced a series of violent changes such as eruptions and earthquakes, while the latter believed that floods of tremendous magnitude would account for gorges, hills of gravel, erratic boulders and other like phenomena. Lyell was not the first person to break away from these more dramatic beliefs, but his "Principles" caught the popular fancy and became an epoch-making volume in geology. After Lyell's death Darwin wrote that he owed almost everything he had done in science to the study of the "Principles."

Charles Lyell was born in 1797. His early interest in natural history may be partly explained by the facts that his father was a botanist of some reputation, and that a severe case of measles kept the boy out of school for six months, during which time he collected insects. His eyesight was so much impaired that his biographer tells us that his shortsightedness caused him to stoop. Since the elder Lyell was well-to-do, it was possible for his son to receive a good education and later to spend much time traveling on the continent.

Although he was admitted to the bar, the study of geology became almost an obsession with him and he gave up everything else so that he could devote himself entirely to this science, then in an embryonic state. Since geology must be studied in the field, as long as his health

permitted, he traveled wherever there was a rock formation, a fossil bed, a changing coast line or any manifestations that might give him a clue to the distant or immediate history of the earth's surface.

During 1841–42 Lyell and his wife visited the United States to make geological observations. The information about fossils, coal mines, erratic boulders, drift and other phenomena must have filled his fellow geologists with joy when "Travels in America," in two volumes, was published in 1845. However, as he traveled from Canada through most of the United States east of the Mississippi he made comments on many things not of a geological nature. One finds these interesting bits about the America of a hundred years ago like nuggets in the less colorful matrix of geological information.

His comments are particularly interesting because they are those of an educated Englishman in a country which was regarded with a raised eyebrow, at least, on the island that had so recently lost the Revolutionary War.

How were the visiting scientist and his wife treated? How did they travel? What impressions did politics, education, the institution of slavery and the important cities make on them? Lyell remarks on all these, never for a moment forgetting that he is an upper-class Englishman, yet at times showing a genuine sympathy toward the struggles and problems he saw everywhere.

Their methods of traveling were varied. They crossed from Liverpool to Halifax by steamboat in eleven days and Lyell thought it amazing that friends in the remote parts of Great Britain would have letters from him in less than a month after his departure. River steamboats were everywhere. The trip from Springfield to New Haven was made in one. On the Hudson he was surprised by the boat which went sixteen miles an hour with a load of five hundred passengers. A long narrow steamer from Brownsville to Pittsburgh impressed him because it drew only eighteen inches of water and the single paddle wheel at the stern threw spray like a fountain. The furnace of this boat was exposed to view and the engineers worked on the deck.

He declared the train service excellent in most parts of the country. Between Schenectady and Niagara Falls the long stretches of swamp and forest land impressed him as much as did the cities that appeared suddenly along the way. A striking example of the rapid change coming to the United States was seen in Rochester, New York, where Oneida Indians sold baskets trimmed with porcupine quills, moccasins and birch-bark boxes on one side of the train, while a well-dressed waiter sold ices and confectionery on the other side. In the suburbs of Baltimore the engines were uncoupled from the trains and the cars were drawn into the city by horses.

It was in the South, not the North, where sleet and ice interrupted one trip. While going from Norfolk, Virginia, to Waldon, North Carolina, a rain storm turned to sleet and snow and it was necessary for the engineer to back the train for half a mile, get up steam, dash forward as far as he could and then repeat the operation until they came to a small watering station where they found lodging in a cottage.

Lyell made several remarks about the fact that women traveled unaccompanied in this country without being annoyed. He also mentioned the presence of rocking chairs for ladies in special rooms in some of the trains in the South.

Trains and boats were common, but there were parts of the country where the Lyells were forced to use coaches, private carriages and even to go on horseback. Stage-coach traveling was not without perils. A fellow passenger told him that he had been tipped over thirteen times within three years on trips

between Cincinnati and Cleveland. It was a stage-coach trip that led Lyell to remark that the "coolness and confidence with which every one here is ready to try his hand at any craft is truly amazing." The occasion for this observation was a very rough ride between Geneseo and Dansville. The coach was drawn by four horses and the driver seemed to delight in hitting all the rough spots and getting into all the ruts. Lyell complained and was informed that this was the driver's first experience driving not only four horses, but any horse at all.

During 1841 and 1842 there was much political and economic turmoil throughout the states besides the ever-growing feeling about slavery. The Helderberg War was in its third year and Lyell found the country people between Schoharie and Albany very much excited because a sheriff's officer had just been severely wounded when in "the act of distraining for rent." Although this war was very limited in area, it is interesting because about 100,000 people were living in a mild feudal system on lands owned by the Van Rensselaer family. The tenants had deeds to their farms but paid an annual rent instead of anything on the principal. Stephen Van Rensselaer had not given much attention to the collection of rents and after his death in 1839 the tenants refused to pay his successor. Their resistance was successful because they, dressed as Indians, carried on a reign of terror. They had about 1,500 men as against 700 militia. Trouble continued until 1850, when a trial suit was decided in favor of Harmon Livingston, the head of a near-by manor. Although the right of title was granted to Livingston, a compromise was made and the tenants on the Rensselaer and Livingston grants were able to buy the farms at fair prices.

During the second year of Lyell's visit he was warned against a railway trip from Boston to Providence because of a local war. This war was over suffrage, for in 1842, Rhode Island was still governed under the charter given it in 1663 by Charles II. Only owners of a freehold worth 134 dollars or renting for seven dollars and the eldest sons of these men had the right to vote. The lower house of the legislature consisted of six deputies from Newport, five each from Providence, Portsmouth and Warwick, and two from each of the other towns. By 1840, Providence had nearly fifteen thousand more residents than Newport, yet Newport was entitled to two more representatives than the larger city. This inequality resulted in the formation of suffrage associations. Then the suffrage associations met in convention and drew up a new constitution. This was voted on favorably and Thomas W. Dorr was elected as governor. The trouble came when the new party tried to take over the government of the state. Governor Samuel W. King called the state militia, which twice dispersed the members of the new party. Dorr was arrested, tried for treason and sentenced to life imprisonment. He was released however in 1847, four years after a constitution framed by the "legal" government was ratified.

This struggle for suffrage and many other incidents made Lyell question the future of a country which allowed nearly every male citizen to vote. He could not believe that it would be very successful and he was confident that no class system could be established. This lack of classes and the hale-fellow attitude of much of the populace distressed him. Lyell was enough impressed by the lack of class feeling to mention the fact that a farmer in New York state had referred to Mrs. Lyell as "the woman" while he spoke of his own daughters as "the ladies." Later in Corning, N. Y., when Lyell wanted his coachman, the innkeeper stuck his head in the bar-room and called out "where is the gentleman who brought this man here?" This consciousness of class was probably not a

personal but rather an English characteristic, for Lyell himself was not knighted until six years after his first visit to America. In one of the rare bits of humor in the book Lyell tells of his indignation when he had to wait from early afternoon until midnight for a coach. The landlord tried to conciliate him by addressing him as "Major."

During the late winter of 1842 the newspapers were full of the extravagant reception given to Charles Dickens. Evidently some Americans thought the matter was being decidedly overdone, but Lyell seemed to think that this adulation was a sign of intelligence, for he reminds the reader that Mr. Dickens was "not a military hero, or a celebrated political character but simply a writer of genius." As far as he was concerned Lyell carried letters of introduction to people in the South in which his friends requested that he be given information and not dinners.

Certainly Lyell's treatment of one celebrated political personage was decidedly brief and unemotional. He disposes of the president (Tyler) in one sentence, "after being presented to the President and visiting several friends to whom we had letters, we were warned by a slight sprinkling of snow that it was time to depart and migrate further southward." The death of President William Henry Harrison, which occurred while Lyell was in this country, is not indexed, but nearly two pages are given to his opinion on the age of the Indian relics near Marietta, Ohio. Here was an English geologist writing in character!

As for the capital of the United States, Lyell was very much discouraged about it. He bemoaned the fact that natural history specimens collected in the Antarctic, the South Seas and California were in the new National Museum in Washington. He felt that it would have been so much more worth-while if they had been at Philadelphia, New York or Boston because they would have been seen there. But Washington had no university, no philosophical societies, no classes in science or literature and no people who appeared to have any leisure. The members of Congress were living in boarding houses and had left their families in the larger cities where the society was more refined.

Boston, with its clubs and societies, and Harvard College in a suburb appealed to him. In Philadelphia the Lyells lost much sleep because of fire alarms. There was an alarm every one of the five nights they stayed there. To be aroused one night by the procession of firefighters might have been interesting, but five nights of excitement were too much, especially since most of the alarms were false. The first runner blew an unearthly sounding trumpet. Behind him a long team of men pulled the fire engine, its large bell clanging incessantly. A mob of men, many with burning torches followed, and behind them another engine. Evidently Lyell complained of this nocturnal racket, because he was told that the youth of Philadelphia required excitement. He wrote one sentence at the end of this description which he probably hoped the Philadelphians would see. It is, "they manage these matters as effectively at Boston without turmoil."

The problems of slavery were in Lyell's mind and he asked himself what he would do if the solution of the problem was suddenly left to him. After much thinking about the matter he could come to no satisfactory conclusion. He was particularly disturbed by the plight of the free educated Negroes in the North.

The interest taken in education, both in schools and by means of libraries and lectures, gave him an opportunity to express his own ideas and to compare the English and the American attitudes.

That the people of Boston should submit to taxes for instruction amounting to about 30,000 pounds sterling gave him much to think about because it nearly equalled the parliamentary grant for the whole of England in 1841. Factory workers interested in evening lectures seemed to puzzle him. Among the titles of lectures he saw advertised were: Temperance; The History of the American Revolution; The Present State and Past History of China; Travels in the Holy Land; and Meteorology. There were also lectures on Phrenology and he made the comment that the Americans put too much credence in that subject.

Taxes were, as usual, a common subject for complaint in 1841–42. He considered that in Pennsylvania the questions of the tax-assessors were inquisitorial, for among other things the taxpayer was asked how many pleasure carriages he kept, how many watches he owned and whether they were gold or silver.

Several states were on the verge of bankruptcy. Money was not under Federal control and travelers found themselves embarrassed because bills given at the point of departure were sometimes of no value at the destination. Personal notes were a new experience to Lyell. He offered one in payment for a carriage he had used to go to Harper's Ferry only to be told that it was no good. In his attempt to explain what a personal note was the driver confessed that once in Baltimore a friend who ran an oyster store told the driver if he would sign twenty-five of these notes and eat their value in oysters he would circulate them. When Lyell asked the driver if his conscience did not bother him, the man replied that the banks had suspended cash payments and that things would be so bad soon that they would have to get better somehow. Lyell comments that the driver and the oyster merchant "had done their best to hasten on so desirable a crisis."

Although he spent little time socially, Lyell commented now and again on people whose names are still well known to-day. With characteristic brevity he mentions going to a ball given by the citizens of Boston in honor of Prince de Joinville, son of Louis Napoleon. It must have been quite a party, because Lyell says it gave him an opportunity to satisfy himself that the beauty of young American ladies had not been exaggerated by foreigners. He heard a sermon by Channing, a great preacher against slavery. He dined with John Jacob Astor, whose name was familiar in England to the readers of Washington Irving's "Astoria." Lyell was delighted that Astor was planning to found a public library in New York City. At his death in 1848 Astor bequeathed $400,000 to the city. The Astor Library was located in Lafayette Place at the time it was consolidated with other libraries to become the New York Public Library.

At New Haven Lyell met Noah Webster. When asked how many words he had coined for his dictionary Webster said that he had never coined but one word, to *demoralize*. He had used it in a pamphlet many years before.

Many more scraps of information are scattered through the book. Lyell saw his first humming bird in New Haven, Connecticut. He smelled his first skunk near Cumberland, Maryland. By 1842, he stated, the leading bands of emigrants had reached the Platte River.

Notwithstanding all the variety of different subjects he mentions, "Travels in North America" is primarily a book on the geology of the Eastern United States. Niagara Falls, the anthracite coal mines, Dismal Swamp, fossil shells and bones, rock formations of every kind are discussed with the thoroughness one would expect from the great English geologist. One of Lyell's outstanding characteristics was his open-mindedness, his willingness to change previously held con-

cepts to conform to new evidence. All through the book one senses that he was at a critical point in his thinking. He was inclined to credit icebergs with the formation of what are now known as glacial deposits and with the scattering of erratic boulders. He was still favoring the iceberg theory in 1842, although he did not fail to mention the fact that other scientists believed that North America had been covered with glaciers. By the time the eleventh edition of the "Principles" appeared in 1866, he had accepted the glacial theory.

Niagara Falls was one of the principal things he had come to see. On August 27th he got his first glimpse of the Falls, as the sun shone on them three miles away. There was no building in view, only the green woods and the river. At first he felt that the beauty of the scene exceeded his expectations, but the Falls were "less grand" than he had expected. Perhaps this feeling of disappointment was the result of having recently seen a plate in a book written by Father Hennepin, who, so far as Lyell knew, was the first European to have seen the Falls. In this drawing made by the French missionary in 1678, the Falls appear nearly twice as high as they should and there is a conspicuous additional falls to the left, looking up the river. However, as the days went by and Lyell studied the effects of the water on the rock strata he was almost awed by the power of moving water. The fixed and unvarying appearance of the water tumbling over the cliff surprised him and he was much impressed by the fact that a daguerreotype picture had been made in which one might actually see not only the rocks but even the shape of the clouds of spray.

Lyell devoted considerable time to the anthracite mines. The coal appealed to him because it burned with so little smoke and did not soil the hands, when touched. But his greatest interests were the method of its formation and the identification of the fossil plants of which it was composed.

After spending a year, lacking about a week, in the United States Lyell left Boston for Halifax. He continued his geological studies in Canada for a few weeks and then returned to England.

Lyell returned to the United States in 1845 and again in 1853 when he was a commissioner to the Industrial Exhibition in New York City.

In 1848 Lyell was knighted and at the time he was summoned to receive the honor he took Prince Albert along the river Dee on a geological trip. The Prince was very enthusiastic. Lyell was made a baronet in 1864.

Now that Lyell had established principles which made it possible to regard geology as a definite science the finding of fossils attained great significance. In 1860 Lyell went to Rhenish Prussia to examine for himself the skull of the Neanderthal Man, then causing great excitement among the scientists. Three years later he brought out the first edition of his now famous "Antiquity of Man." This book went through four editions in ten years.

Sir Charles Lyell died in 1876 and was buried in Westminster Abbey. It has been said of this pioneer geologist, "so long as Lyell lived he learned." What greater tribute could be given to a scientist? Yet probably very few people know anything about his visits to the United States in the last century, or have any knowledge of the importance of the man whose name was given to a mountain in California, near the Yosemite.

ELECTRON MICROSCOPES AND THEIR USES

By Dr. JOSEPH A. BECKER and Dr. ARTHUR J. AHEARN

BELL TELEPHONE LABORATORIES

THREE and a half centuries have passed since Zacharias Janssen, a spectacles maker of Middleburg, Holland, put two lenses in a six-feet-long tube and thereby made the first known compound microscope. In the years since then, the microscope, now grown into a powerful and intricate instrument, has played an important role in the discovery of much of man's knowledge of the physical world. There is, however, much that the microscope has been unable to reveal because of its limited range of useful magnification. To-day, a new type of magnifying instrument, the electron microscope, is extending the range of useful magnification far beyond its old limits and promises to supplement the traditional microscope in many fields of scientific research. In this article, we shall describe types of electron microscopes, tell how they function, and outline how they are being used in physics, chemistry, metallurgy and the biological sciences. A number of pictures will be shown to illustrate these uses.

The electron microscope is similar in the general nature of its operation to the light microscope. In both microscopes, the light waves or the electrons, as the case may be, coming from the object are focused upon an image plane to form a magnified image of the object. No microscope, however, can do this focusing with complete accuracy; hence, there is a limit to the greatest useful magnification that any particular type of microscope can give. For light microscopes this limit is determined largely by the wavelength of the light; thus, with a high-powered microscope of the usual design, we can magnify an object until it is possible to distinguish points on it which are separated by about half a wavelength but any further magnification results in a blurred image. Unfortunately, light waves are so long that the limit of useful magnification for the usual type of light microscope is only about a thousand fold. This limit of useful magnification has been increased by designing microscopes which employ the shorter ultra-violet light waves and by designing ones in which the space between the object and the lens system is filled with liquids of high refractive index. However, until the advent of the electron microscope, the highest useful magnifications available were but a few thousand fold, and there seemed little prospect that this value would ever be substantially increased.

In 1926, H. Busch showed that beams of electrons could be focused by magnetic fields. Subsequently such beams were also focused by means of electric fields. The development of the electron microscope followed naturally from the discovery of these electron-lens properties of electric and magnetic fields. When the wave nature of the electron was first demonstrated by Davisson and Germer in 1927, the very short wavelengths associated with electrons suggested that this type of microscope should yield useful magnifications far greater than those obtained with light microscopes. This has been verified by experiment. Several different types of electron microscopes have been developed; useful magnifications of almost a million fold have been obtained.

While there is a certain similarity between the electron and the light microscopes, they differ in several important respects: the method of focusing, the

manner of observing the image, the way in which the details of the object are distinguished, and the sources of illumination.

The focusing in electron microscopes is brought about either by magnetic fields, electrostatic fields or a combination of these two. These fields change the path which the electrons follow in much the same way as an optical lens changes the path of light rays. Magnetic "lenses" consist of permanent magnets or electromagnets, while electrostatic "lenses" consist of charged plates with apertures or of coaxial cylinders placed end to end. The magnets or plates are so designed that the magnetic or electric fields have a high degree of symmetry about one axis. These fields must also be so disposed that all electrons coming from a point on the object will again come together at or very near a point in the image plane. This focusing is usually done by changing the potential of one of the plates or by changing the current in one of the electromagnets rather than by changing the relative position of the object, lens and image. The relative position of these parts determines the magnification, and to get high magnifications the object-lens distance must be small while the lens-image distance must be large. Certain simple forms of electron microscopes do not employ lenses. In these the image is formed by a radial projection of electrons from the object-cathode to a screen.

In an optical microscope, we usually see the image directly by looking through the microscope eye-piece, but since electrons are not visible, this can not be done in the electron microscope. By placing a fluorescent screen at the image plane, however, the electron image becomes visible, each part of the screen fluorescing in proportion to the number of electrons hitting it, and the electron density pattern is converted into a visible image. The pattern can be recorded either by photographing the image on the fluorescent screen or by placing a photographic plate directly in the image plane.

When viewed through an optical microscope, the size, the shape and the other details of an object are revealed because different areas transmit or reflect light with different intensities. Similarly, when an object is viewed through an electron microscope, these details can be distinguished because the different regions transmit or emit electrons in varying amounts. An object may appear quite different in the two types of microscopes. Areas which transmit or reflect light with greatly different intensities may transmit or emit electrons with almost equal intensities, and *vice versa*. Certain bacteria, for example, which can not be seen with an optical microscope unless they have been dyed, can be seen with the electron microscope in their natural state. Frequently, however, as we shall see in several of the illustrations, photographs made with the two kinds of microscopes appear very similar.

Although the two kinds of illumination, *i.e.*, electrons and light, differ radically, there is a similarity in the way they are used in various types of the two microscopes. Corresponding to light microscopes in which the light (1) goes through a thin object, (2) is reflected from an opaque object or (3) come from a self-luminous object, there are electron microscopes in which the electrons (1) pass through a thin object, (2) are reflected from a thick object or (3) come directly from an electron-emitting object. Most of the usual methods of causing a surface to emit electrons have been used: heating the object yields thermionic electrons; shining light onto it yields photoelectrons; bombarding it with electrons yields secondary electrons; and subjecting it to intense electrical fields yields field electrons. In studying metals and electron emission problems, a microscope

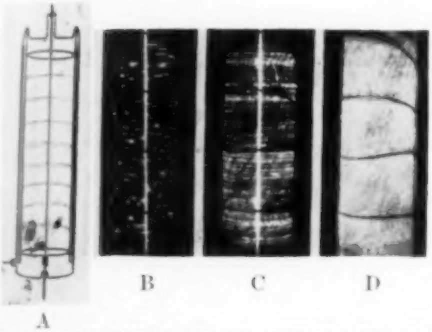

FIG. 1. CYLINDRICAL ELECTRON MICROSCOPE AND PHOTOGRAPHS OF THORIATED TUNGSTEN FILAMENT IN DIFFERENT STAGES OF ACTIVITY TAKEN WITH IT: (A) SKETCH OF MICROSCOPE; (B) FILAMENT AFTER PRELIMINARY TREATMENT; (C) FILAMENT PARTIALLY ACTIVATED; (D) FILAMENT COMPLETELY ACTIVATED (JOHNSON AND SHOCKLEY).

employing one of the above methods of obtaining an emission of electrons from the surface of the object is used. Microscopes in which the electrons are transmitted through the body of the object are used for studying biological specimens and colloidal suspensions. With this as an introduction, let us turn to a description of some of the actual microscopes.

The simplest of the electron microscopes is the cylindrical one developed by Johnson and Shockley, and shown in Fig. 1A. The object, in the form of a fine filament, is placed in the axis of the glass tube, the inner surface of which is coated with a fluorescent screen. The anode consists of a cylindrical spiral of wire in contact with the screen. The tube is evacuated. When the filament is heated and a potential difference of a few thousand volts is applied between the filament and the anode, the thermionic electrons travel radially from the filament toward the screen. There an electron image of the emission pattern of the filament appears. This image is distorted, since along the circumference of the filament the magnification is equal to the ratio of the screen radius to the filament radius but along the length of the filament the magnification is unity.

The pictures shown in Fig. 1B, C and D are of a thoriated tungsten filament in different stages of its activity; they are typical of those obtained with the cylindrical microscope. In B, the wire

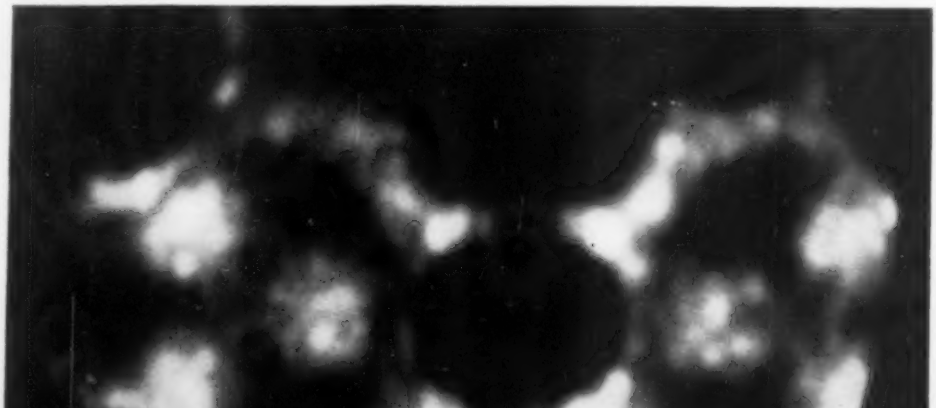

FIG. 2. SINGLE CRYSTAL OF TUNGSTEN ON WHICH BARIUM HAS BEEN DEPOSITED—MAGNIFICATION: 250,000 DIAMETERS (BECKER).

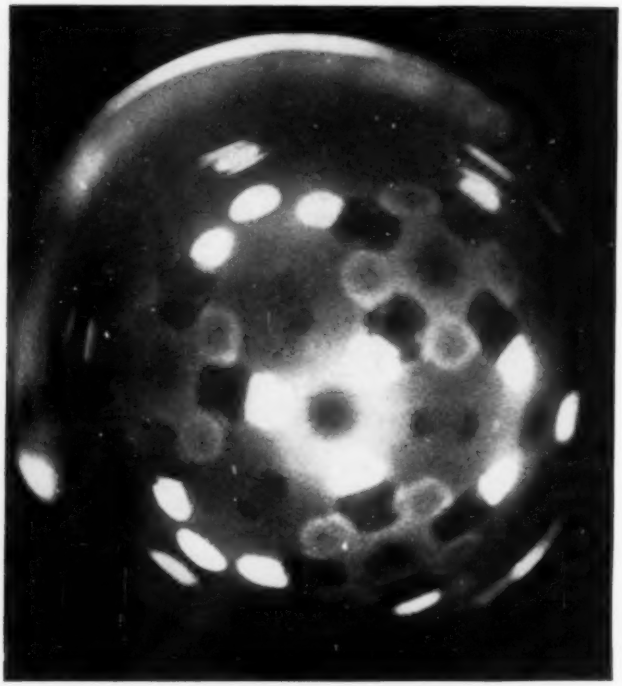

FIG. 3. SINGLE CRYSTAL OF NICKEL—MAGNIFICATION: 200,000 DIAMETERS (M. BENJAMIN, GENERAL ELECTRIC CO., LTD., ENGLAND).

has received only preliminary treatment. The small bright lines correspond to small spots where thorium has come to the surface of the tungsten and where, therefore, electrons are emitted more copiously than elsewhere. In C, the filament has been heated at an activating temperature of 1900° K for a short time. There are more spots and they are longer, indicating that thorium has come to the surface at more places and that it has spread out over a larger area for each active spot. In D, the filament has been fully activated; the bright lines have run together as thorium now covers the entire surface. The horizontal dark lines in these pictures were caused by the anode wires; the more or less vertical streaks in D, by die marks on the surface of the filament. How thorium comes to the surface of this filament is one of the many interesting stories that the electron microscope has revealed; it will be told more fully a little later.

In a second popular type of simple microscope, one developed by Müeller, the cathode consists of a small wire the end of which has been etched to a fine point. This "point," which is actually a hemisphere of very small radius, is mounted at the center of a spherical glass bulb whose inner surface is coated with fluorescent material. When a potential of a few thousand volts is applied to the screen, electron field currents are emitted from the filament. They travel radially to the screen, where an image of this emission appears magnified in the ratio of the screen diameter to the cathode point diameter. Magnifications of half a million or more can be obtained.

If the cathode point is sufficiently small, it will usually consist of only one

crystal. The image on the screen then shows the electron field emission pattern of the various faces of this crystal. Such an image of a single crystal of tungsten on the surface of which there is a small amount of barium is shown in Fig. 2. Here, dark and bright regions form the symmetrical pattern which is characteristic of cubic crystals, such as those formed by tungsten. The small bright spots are places where individual barium ions are adsorbed on the surface. They appear because the electron field emission

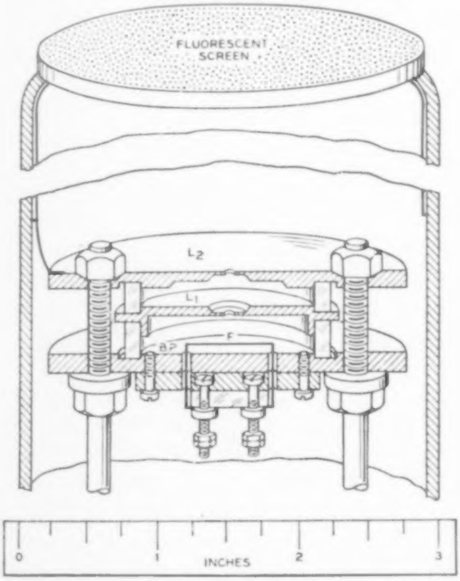

FIG. 4. SKETCH OF MICROSCOPE USING ELECTROSTATIC LENSES (AHEARN AND BECKER).

is enhanced in the neighborhood of each adsorbed ion. A similar photograph of a crystal of nickel shows an interesting and well-ordered pattern (Fig. 3). The magnification for Fig. 2 is 250,000 times; for Fig. 3, about 200,000 times.

Another type of microscope, one developed by Dr. C. J. Davisson and Mr. C. J. Calbick, employing electrostatic lenses, is shown in Fig. 4. The object F, is usually a narrow ribbon of metal which, when heated, emits thermionic

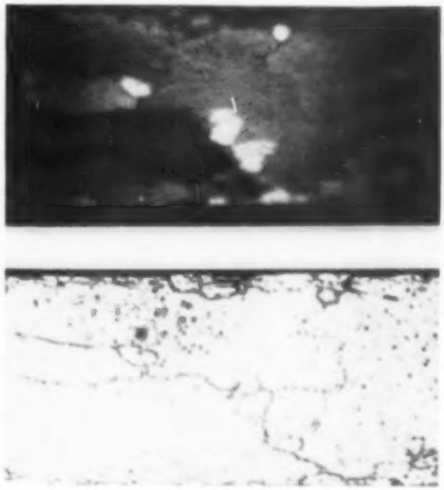

FIG. 5. COMPARISON OF ELECTRON AND LIGHT MICROSCOPE PICTURES OF THORIATED TUNGSTEN RIBBON—TOP: ELECTRON MICROSCOPE PICTURE, BOTTOM: LIGHT MICROSCOPE PICTURE (AHEARN AND BECKER).

FIG. 6. THE FIRST COMMERCIALLY BUILT ELECTRON MICROSCOPE IN AMERICA. IT WAS DEVELOPED AND BUILT BY THE R.C.A. LABORATORIES (AMERICAN CYANAMID CO.).

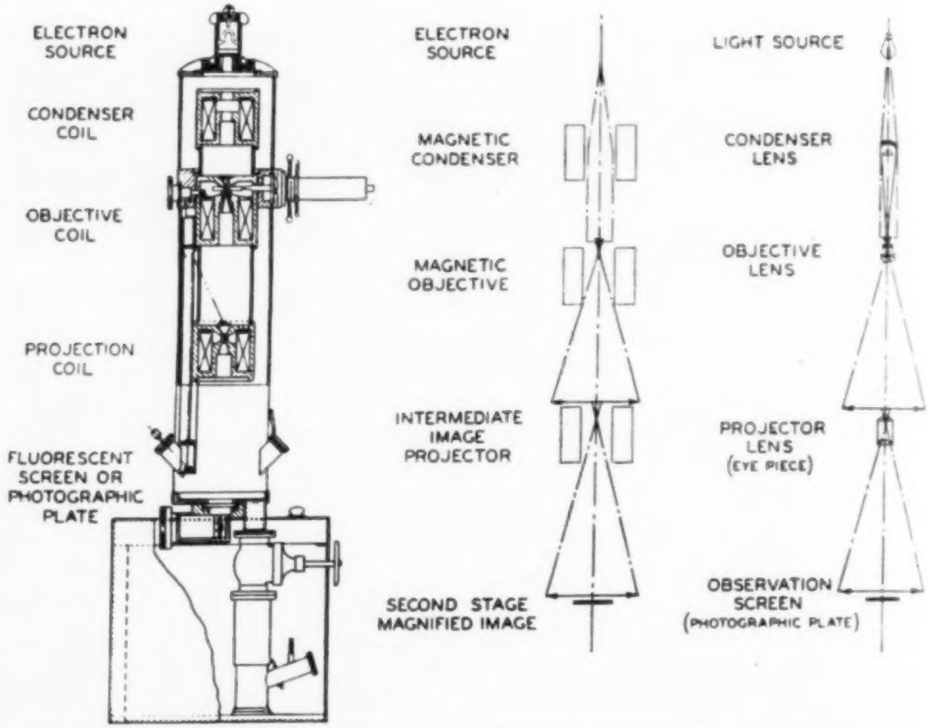

FIG. 7. SCHEMATIC OF "SUPERMICROSCOPE" AND LIGHT MICROSCOPE (R.C.A. LABORATORIES).

electrons. Some of these pass through the small holes in the lenses L_1 and L_2 and are focused onto the fluorescent screen so that they form there a magnified pattern of the object's surface. In a typical case, the potential on L_2 might be two kilovolts and that on L_1, a tenth as much. With microscopes of this design, magnifications of 50 to 500 are easily obtained.

A picture of a thoriated tungsten ribbon taken with this microscope appears in Fig. 5, together with one taken with a light microscope. A comparison of these pictures shows an excellent agreement in crystal structure as revealed by the two types. Both reveal the grain boundaries as a closely packed series of dark spots, but we notice a much greater difference in electron emission than in light reflection for the various crystals.

The most widely publicized of the electron microscopes, namely the "supermicroscope," uses transmitted electrons and magnetic lenses. This microscope is used to see very thin objects through which a stream of electrons is projected. Microscopes of this kind have been developed by von Borries and Ruska in Germany, by E. F. Burton and his associates at the University of Toronto and by Marton, Zworykin and their associates at the R.C.A. Laboratories. One of these is shown in Fig. 6, and a schematic of it as compared to a light microscope is shown in Fig. 7. A beam of about 50-kilovolt electrons coming from a source at the top of the microscope is made parallel by the condenser lens. The beam then strikes the specimen, which has been placed near the objective lens. Different regions of the specimen absorb or scatter electrons in varying amounts. The electrons pass-

ing through the specimen form a density pattern which the objective lens focuses into an intermediate image. This image is magnified by the projector lens, and the final image is formed near the base of the microscope. Useful magnifications as high as 100,000 times have already been obtained with this microscope and points on the object separated by only a millionth of a cm have been resolved.

Objects to be examined with this microscope are usually mounted on thin sheets of nitro-cellulose. Delicate objects are easily damaged by the intense electron beam. Special techniques have been developed for mounting specimens and inserting them into the highly evacuated chamber. A recently developed form of this microscope has a light microscope built into it, thus permitting simultaneous observation of an object by light and by electrons.

The pictures included in Figs. 8 to 10 show the type of image obtained with the supermicroscope. The first of these compares photographs of *Bacterium coli* taken with the electron microscope and with a light microscope. Both photographs have been enlarged to correspond to an overall magnification of 10,000 times. It is apparent that the amount of detail revealed and the resolving power are much greater with the electron microscope than with the light microscope. Fig. 9 is of a thin filament of a plasticized polymer of vinyl chloride containing 2 per cent. carbon black, magnified 105,000 times. This is a synthetic rubber-like material manufactured by Goodrich. The smallest particles that can be seen here may well be single molecules. In Fig. 10, we can see a particle of face powder, magnified 25,000 times.

Another type of microscope is one employing either photoelectrons or secondary electrons. One use of this microscope is to facilitate the observation of objects by infra-red rays. Infra-red rays that have passed through or have

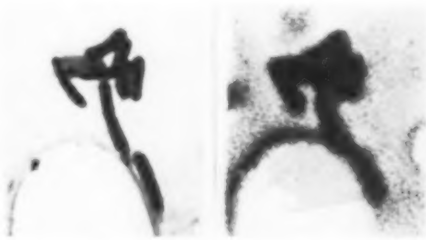

FIG. 8. BACTERIUM COLI. LEFT: ELECTRON MICROSCOPE. RIGHT: LIGHT MICROSCOPE. MAGNIFICATION: 10,000 DIAMETERS (VON BORRIES AND RUSKA).

been reflected by an object are projected onto a surface which emits electrons when it is illuminated. The emitted electrons are then focused on a fluorescent screen where they form an enlarged picture of the object. When secondary electrons are used, the object is bombarded by primary electrons; if parts of its surface have different secondary electron characteristics, we get a pattern revealing the structure of the surface.

Some Uses of the Electron Microscope

Some of the uses for the electron

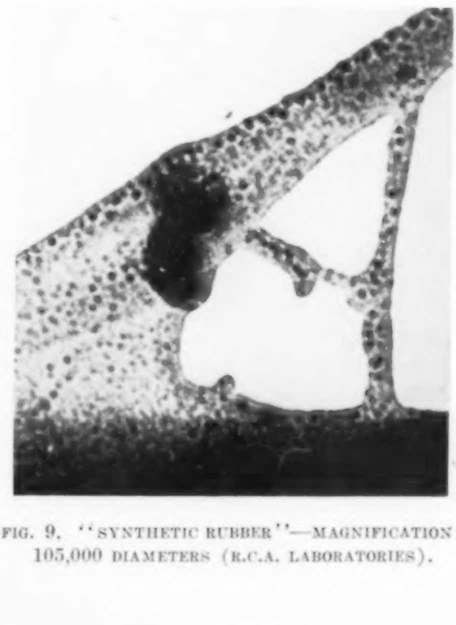

FIG. 9. "SYNTHETIC RUBBER"—MAGNIFICATION: 105,000 DIAMETERS (R.C.A. LABORATORIES).

microscope have already been suggested. We shall now turn to a detailed discussion of its use in the fields of physics, chemistry, metallurgy and biology, and particularly in the fields of thermionic emission and adsorption phenomena in which the authors have been chiefly interested.

One of the earliest uses of the electron microscope was the study of thermionic emission, a particular instance being the emission from thoriated tungsten. When a thoriated tungsten filament has been properly treated, the electron emission from it is about 100,000 times greater than that from a pure tungsten filament at the same temperature. For this reason, thoriated tungsten filaments are used in vacuum tubes. These filaments contain small globules or inclusions of thorium oxide amounting to 1 or 2 per cent. of the volume of the filament. The wires are heated at a high temperature momentarily and then at about 1800° K until a layer of thorium about one atom thick covers the entire surface.

The way in which the thorium arrives on the surface has long been discussed. By using the microscope designed by Dr. Davisson, we have observed how the thorium diffuses to the tungsten surface,

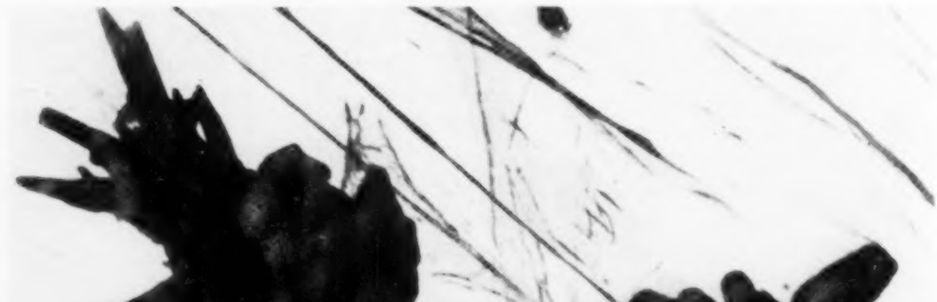

FIG. 10. FACE POWDER—MAGNIFICATION: 25,000 DIAMETERS (R.C.A. LABORATORIES).

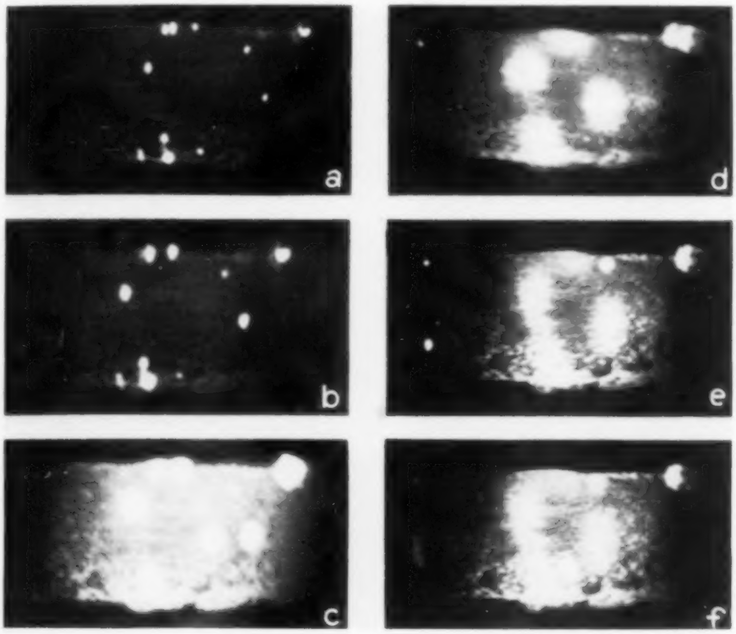

FIG. 11. THORIUM ERUPTIONS ON A SMALL GRAINED THORIATED TUNGSTEN RIBBON (AHEARN AND BECKER).

how it migrates and evaporates and how the crystal structure of the tungsten influences these processes.

Two series of pictures of thoriated tungsten filaments, taken while they were being activated, appear in Figs. 11 and 12. Fig. 11 shows a fine-grained filament. The first picture was taken after the filament had been flashed at 2500° K. Here there are a few bright spots of high electron emission where the thorium has come to the surface. The following pictures were taken after the filament had been heated successively longer times at its activating temperature of 1800–1900° K. The spot in the right center region shows a typical history. It grows both in size and intensity for a while and then becomes dimmer as its size further increases. Other spots go through the same sequence, but their sizes at maximum intensity vary considerably. Occasionally new spots appear and, in turn, go through the same sequence.

Fig. 12 shows the activation of a coarse-grained filament. Here the spots are much larger: in *d*, one of them has covered the entire width of the filament. In *b*, we see two spots on a single crystal which are growing more rapidly in one direction than in others. In *c*, there is a spot which has just started at the junction of several grain boundaries.

From these pictures, we can see that the thorium comes to the surface through a small opening and then spreads out and that only a limited amount of thorium comes through any one opening. Because of the resemblance to volcanic eruptions, these phenomena are known as "thorium eruptions." We are led to the hypothesis that these eruptions are caused by the thorium oxide inclusions in the tungsten and that when an eruption occurs, all the oxide in a single

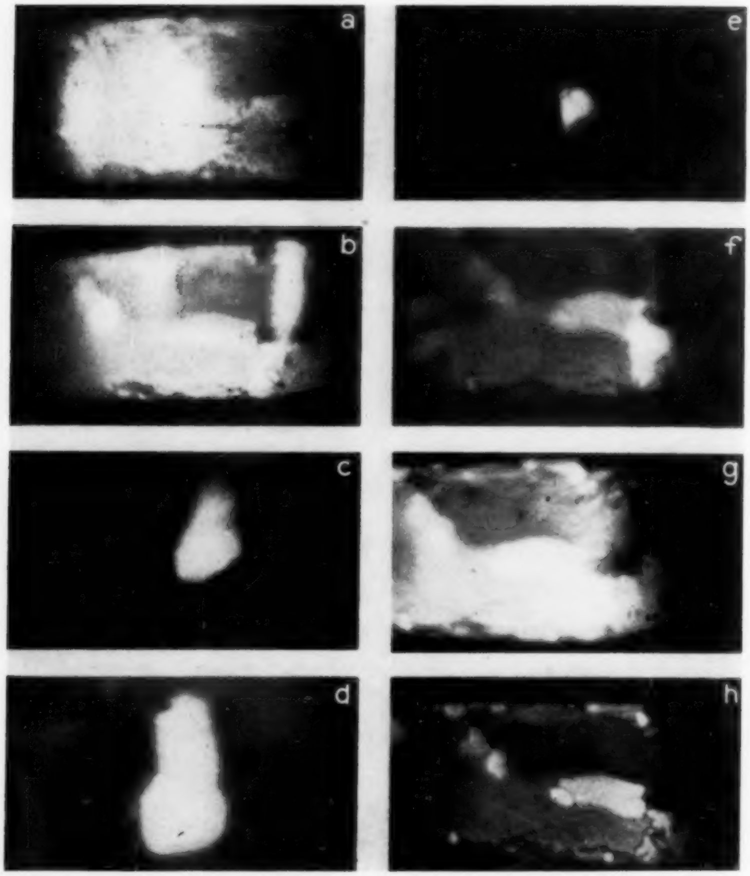

FIG. 12. THORIUM ERUPTIONS ON A LARGE GRAINED THORIATED TUNGSTEN RIBBON (AHEARN AND BECKER).

inclusion is reduced to metallic thorium, which then comes to the surface.

Photomicrographs of sections of these thoriated tungsten filaments show the inclusions. Such a photomicrograph for the fine-grained filament is in Fig. 13. On the large grain filament the inclusions are larger than on the small grain one. They tend to congregate along the grain boundaries. Their total volume amounts to about 2 per cent. of that of the filament, and their distribution in size agrees well with that calculated from the electron images of thorium eruptions. All these facts confirm the hypothesis that when an eruption occurs, approximately all the thorium in an inclusion of thorium oxide comes to the surface.

When eruptions occur on a polycrystalline filament, the thorium migrates with equal ease in all directions. This was shown in Fig. 11. When these eruptions occur on a single crystal, the thorium tends to migrate in a preferred direction. This is shown in Fig. 14. From x-ray studies of this crystal, the preferred direction was found to be the 111 direction on a 211 plane. In this direction, the neighboring rows of tung-

sten atoms are the most widely separated, and evidently the potential hills which a migrating thorium atom encounters are the smallest.

How the emission from various crystals of tungsten depends on the amount of adsorbed thorium can be seen in Fig. 15. Picture *a* is an electron image of a tungsten surface on which there is only a small amount of thorium; picture *b* is of tungsten with a high concentration of thorium; the following ones represent successively lower thorium concentrations. We see a number of crystals which are relatively bright in *a* and relatively dark in *b*. In pictures *d* and *e*, which correspond to intermediate concentrations of thorium, the contrast between different crystals is slight. This reversal of pattern must mean that if crystal A is less active than B when their surfaces are clean, then A will be the more active of the two when sufficient thorium is adsorbed on their surfaces.

The spherical microscope has been used successfully to study the electron emission of tungsten surfaces on which barium has been deposited. In Fig. 2, we saw a single crystal of tungsten with a small amount of barium on its surface. Because of this barium, the bright regions in the pattern do not appear uniformly bright. Apparently the electron emission comes mainly from small spots, five or six atomic distances in diameter, on the tungsten surface. We believe these spots are caused by individual barium ions. Because these ions are positively charged and are close to the surface, they produce strong fields in their neighborhood. These fields range as high as 10 million volts per cm very close to the ions and probably have high values for distances of several atom-diameters from them; as these fields are in the same directions as the one caused by the applied potential, the electron emission near these ions is much greater than elsewhere. If the number of these spots in a given area is counted, it is possible to compute the decrease in work function for such a surface. This computed decrease agrees with that observed experimentally. Occasionally a spot becomes brighter for ten to thirty seconds or disappears temporarily. In the latter case, we believe the ion has attracted an electron and has become temporarily a neutral atom. When the spot becomes unusually bright, we believe the ion has lost a second valence electron and thus the field near it has become even higher than before. It is

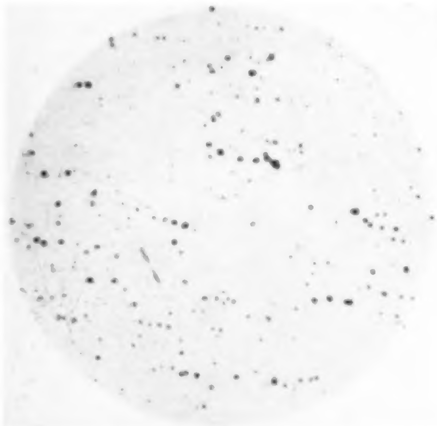

FIG. 13. PHOTOMICROGRAPH OF INTERIOR SECTION OF FINE GRAINED THORIATED TUNGSTEN RIBBON. MAGNIFICATION: 850 DIAMETERS (AHEARN AND BECKER).

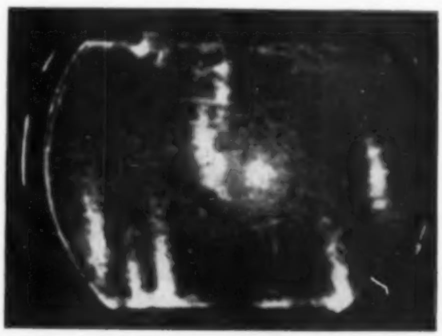

FIG. 14. MIGRATION OF THORIUM OVER THE SURFACE OF A SINGLE CRYSTAL OF THORIATED TUNGSTEN (AHEARN AND BECKER).

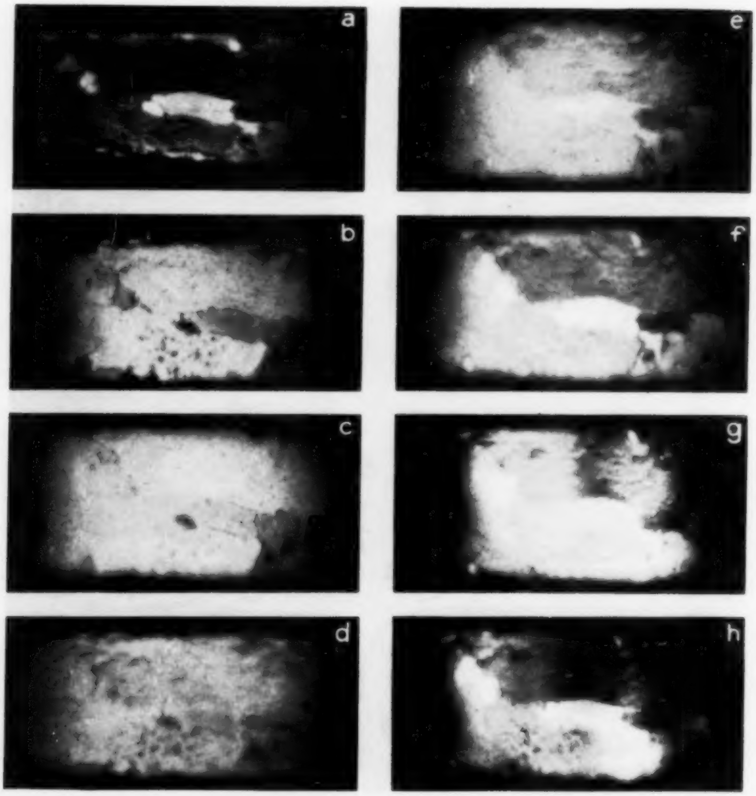

FIG. 15. CHANGE OF ELECTRON EMISSION FROM TUNGSTEN RIBBON WITH CHANGE IN AMOUNT OF ADSORBED THORIUM. A. LOW THORIUM CONCENTRATION; B. HIGH THORIUM CONCENTRATION; C TO H. SUCCESSIVELY LOWER THORIUM CONCENTRATIONS (AHEARN AND BECKER).

only with low barium concentrations that these spots can be observed; as the amount of barium is increased, the spots become more numerous and run together.

If this tungsten point is heated to 840° K, the spots at the edges of the central area begin to move about. When the temperature is further increased, all the spots become agitated, and individual spots merge with their neighbors. This demonstrates that these ions are not rigidly anchored to the tungsten, that they bounce about over the surface. When their average kinetic energy, which increases with temperature, becomes great enough, this "thermal agitation" becomes visible in the microscope. If the barium is deposited only on one side of the tungsten point, it is possible to observe the barium migrate to the other side and cover the whole surface. This migration begins at about 900° K.

As the amount of barium on the point is increased, the anode potential that is needed to get a visible image on the screen decreases. With increased barium, the distribution of the bright and the dark regions changes, but the symmetry stays the same. If thorium is substituted for barium, similar results are obtained. This is beautifully shown in Fig. 16. The pictures, from the work

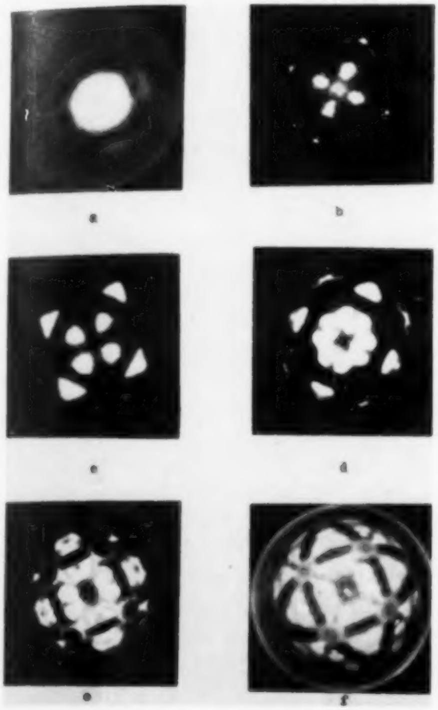

FIG. 16. TUNGSTEN SINGLE CRYSTAL POINT WITH PROGRESSIVELY LARGER AMOUNTS OF ADSORBED THORIUM (AMOUNT OF THORIUM INCREASED FROM A TO F) MAGNIFICATION: 91,000 DIAMETERS (M. BENJAMIN, GENERAL ELECTRIC CO., LTD., ENGLAND).

of Dr. M. Benjamin, represent progressively larger amounts of thorium on a single tungsten crystal. The same symmetry appears whether the surface is clean or is heavily coated with thorium.

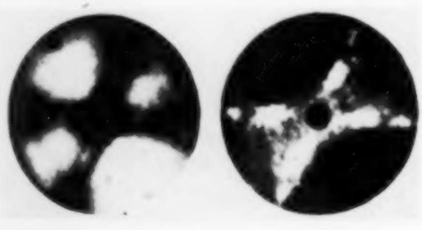

FIG. 17. EFFECT OF ADSORBED OXYGEN ON EMISSION FROM TUNGSTEN: LEFT, CLEAN TUNGSTEN; RIGHT, TUNGSTEN COVERED WITH OXYGEN (MÜELLER, BERLIN).

It is interesting to note that as the thorium concentration changes, some of the dark areas become the brightest ones, and *vice versa.*

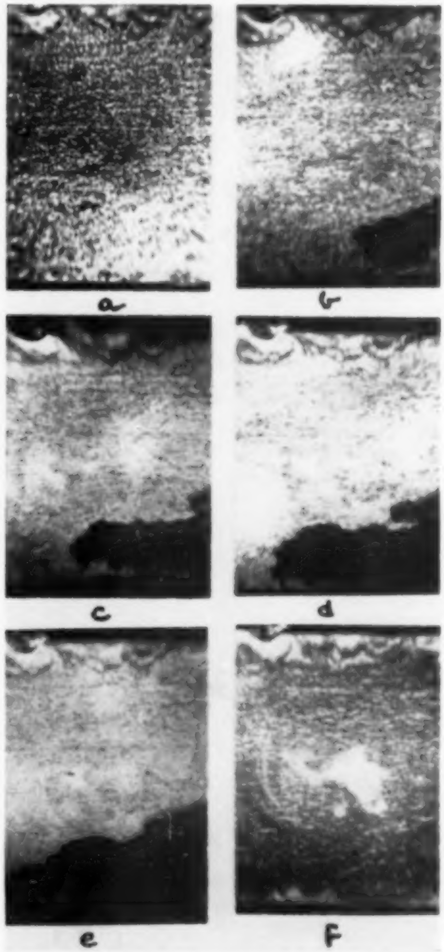

FIG. 18. GRAIN GROWTH IN THORIATED TUNGSTEN. A. 2400° K, 60 MINUTES; B. 2600° K, 4 MINUTES; C. 2600° K, 2 MINUTES; D. 2600° K, 1 MINUTE; E. 2630° K, 1 MINUTE; F. 2700° K, 30 SECONDS (AHEARN AND BECKER).

The spherical microscope has also been used to study adsorption of oxygen. With this microscope, the field emission pattern of a clean tungsten crystal can be observed and compared with the pat-

tern of the same crystal after a large amount of oxygen has been adsorbed by its surface. Such a comparison is illustrated in Fig. 17 and reveals a reversal in pattern similar to that noted in the discussion of the effects of large amounts of thorium on the thermionic emission of tungsten. The oxygen, however, hampers rather than facilitates the emission; twice as high a field is required to observe the oxygen contaminated surface as is needed to observe the clean one. When the tungsten is heated at successively higher temperatures to reduce by steps the amount of oxygen, the pattern changes in a complicated way and finally returns to that corresponding to the clean surface. From such changes in the activity of various parts of a crystal surface, the physicist and the chemist can learn something of the forces in adsorption and of the charges on adsorbed atoms and ions—forces and charges that play a deciding role in catalysis. It seems probable that the electron microscope will prove of considerable value in the study of these important phenomena.

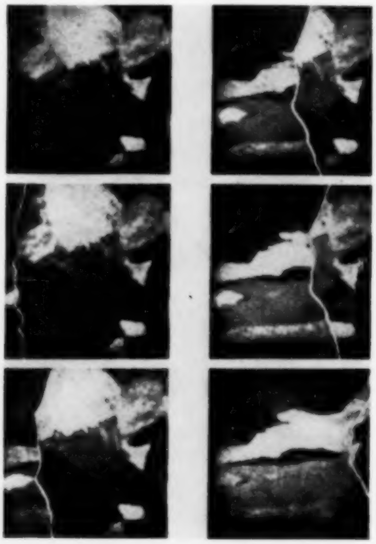

FIG. 19. CRYSTAL TRANSFORMATION IN IRON. TO LEFT OF WHITE LINE: BETA IRON. TO RIGHT OF WHITE LINE: GAMMA IRON (BURGERS AND PLOOS VON AMSTEL).

The now familiar difference in the electron emission from different crystal faces of the same metal has suggested the use of the electron microscope to the metallurgist. In particular, it gives him an easy method of studying grain growth and crystal transformations in metals by permitting continuous observation of these changes as they occur. Fig. 18 shows this grain growth in thoriated tungsten as revealed by such a use of the electron microscope. In *a* the filament had been heat-treated at 2400° K only for about 60 minutes. In the succeeding pictures, short-time heat treatments at 2600° K to 2700° K were given. The large grain growth first appears in the lower right-hand corner and eventually absorbs most of the field of view into a single crystal. In *f*, a little island of the original polycrystalline tungsten still persists. As a result of further heating, this island was completely absorbed into the single crystal.

Another example from the field of metallurgy showing how the electron microscope makes short work of otherwise tedious jobs is the study of crystal transformation in iron. Above 906° C iron atoms arrange themselves in the face-centered cubic lattice; this is known as the Gamma phase. Below 906° C they are arranged in the body-centered cubic lattice; this is called the Beta phase. Fig. 19 shows a series of electron images in which Gamma iron is transformed into Beta iron. To photograph these electron images, the iron was first covered with strontium in order to get a satisfactory electron emission at the transformation temperature. The first picture is that of Gamma iron slightly above 906° C. In the following ones, the temperature has been reduced below 906° C. Since a temperature gradient

FIG. 20. PHOTOGRAPHIC GRAINS. LEFT: A SILVER BROMIDE CRYSTAL WHICH HAS BEEN DEVELOPED BY THE USUAL CHEMICALS. CENTER: A LIPPMANN EMULSION MADE BY PRECIPITATING COLLOIDAL SILVER BROMIDE. RIGHT: THIS EMULSION AFTER CHEMICAL DEVELOPMENT. EACH CRYSTAL WAS LENGTHENED INTO A THREAD ABOUT 5 ATOMS THICK. MAGNIFICATION 125,000 DIAMETERS (EASTMAN KODAK RESEARCH LABORATORY).

exists along the wire because of end-cooling, the transformation begins at the end (the left in these pictures) and progresses toward the center. A white line has been drawn on the pictures to show the boundary between Beta iron on the left and Gamma iron on the right. By raising the temperature above 906° C, the iron is reconverted into the Gamma phase. Similar use has been made of this microscope to study the same type of transformation in other metals.

Use of the transmitted-electron type of microscope has revealed a variety of phenomena of interest to colloidal chemists and to bacteriologists. In one study, it was found that the silver grains in a

FIG. 21. FINE PARTICLES OF MAGNESIUM OXIDE. MAGNIFICATION: 56,000 DIAMETERS (AMERICAN CYANAMID CO.).

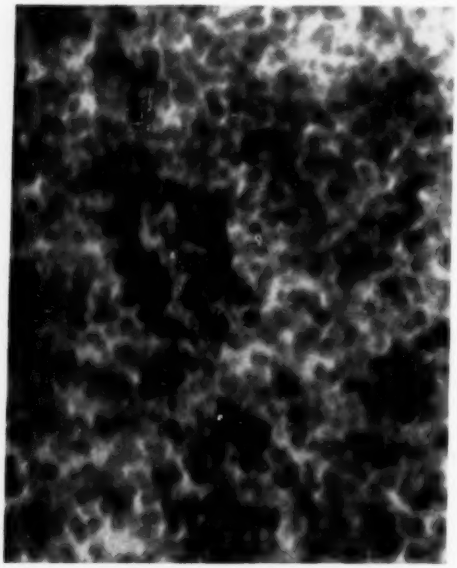

FIG. 22. COLLOIDAL CARBON BLACK PARTICLES. MAGNIFICATION: 48,000 DIAMETERS (A. PREBUS AND COLUMBIAN CARBON CO.).

photographic film resemble loose balls of thread rather than compact particles (Fig. 20). Work on fine powders has revealed that very minute particles have the same crystal structure as the corresponding large particles, thus disproving a widely held theory (Fig. 21). From photographs, such as the one in Fig. 22, the size and shape of colloidal carbon particles have been determined. The size of these particles, which has long been the subject of research, was found to be considerably smaller than that revealed by earlier techniques.

Examination of bacteria by means of this microscope has revealed that many types of bacteria, including streptococci, pneumococci, bacillus subtilis, coliform and typhoid bacilli, have rigid outer membranes or shells which protect their inner structure. Other bacteria have been found to have long, apparently tubular arms by means of which they probably are able to move around. An investigation of the reduction of tellurides to metallic tellurium by diphtheria bacilli showed that crystals of tellurium form in all parts of the microorganism and that, in some cases, the crystals grow large enough to puncture the walls of the bacillus. The electron microscope has also been used to locate magnesium and calcium in striated muscle tissue. A number of photographs made with this microscope of microorganisms were included in a recent issue of THE SCIENTIFIC MONTHLY[1] and show some of the interesting details that the electron microscope has revealed.

We hope that this review of various electron microscopes and their uses has served as an introduction to this interesting new instrument. How greatly the electron microscope will contribute in the future to an increased knowledge of nature and to the advancement of man, one can only guess. But, with the light microscope still proving of immense value after centuries of use, it seems more than likely that the contributions of the electron microscope will prove both numerous and significant as its development progresses and its use becomes wide-spread.

The authors acknowledge with thanks the valuable assistance of Mr. E. P. Churchill, Jr., in preparing this manuscript.

[1] T. A. Smith, SCIENTIFIC MONTHLY, 52: 4, 337, April, 1941.

ASPECTS OF URBAN AND INDUSTRIAL GEOGRAPHY IN TASMANIA

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TASMANIA affords opportunities for the study of urban centers and tributary rural districts in relatively mature stages of development under the Australian environment. Most mainland states are less far advanced in the exploitation of natural resources, and their populations continue to expand at fairly rapid rates, especially in the larger cities.

In Tasmania agricultural activities, which have always been the backbone of development, display few signs of expansion or change. Little new land is available and specialized forms of agriculture, for which Tasmania has certain inherent advantages, are more significant than general pastoral or farming activities. Known mineral deposits of better grade and the more accessible timber supplies have been largely exhausted with the inevitable effects on dependent population groups. Manufacturing enterprises of many types have declined in competition with larger establishments on the mainland, although the development of cheap hydroelectric power has recently brought several important new industries to the island. Recreational activities afford an increasingly important source of income to an area steeped in tradition and scenery and situated on the periphery of modern Australian development.

Tasmania's rate of population growth has been least rapid among all the Australian states since the beginning of the twentieth century. In numerous years, especially since 1918, the population has shown substantial losses due largely to emigration but due also to declining birth rate. Although the larger cities show a slow growth, urban opportunities are insufficient to prevent a considerable migration of young people to the nearby mainland.

Tasmania is least highly urbanized among the Australian states. Only 52 per cent. of her population of nearly a quarter million resides in cities as compared to 69 per cent. in New South Wales. Tasmania also ranks lowest among the states in the proportion of its population concentrated in the capital city. Hobart and its suburbs contain only 27 per cent. of the state's population as compared to 55 per cent. in Melbourne. Fifteen per cent. of Tasmania's population is concentrated in Launceston, thus giving the island a second city of great relative importance.

The lesser degree of centralization of population, commerce and industry in Tasmania has its origin in the historical development of the state as well as in the arrangement of physical forms. Hobart and Launceston, by virtue of their early establishment at strategic positions at the north and south ends of the island, command the trade of the state and dominate most aspects of its political, social and economic life (Fig. 1).

An examination of the circumstances surrounding the original selection of the sites for Tasmania's two principal foci of settlement, coupled with a brief account of their early growth, affords a helpful background for understanding later aspects of the state's urban and industrial development. The high degree of success to which sites originally selected for penal purposes later served as centers for modern urban activities

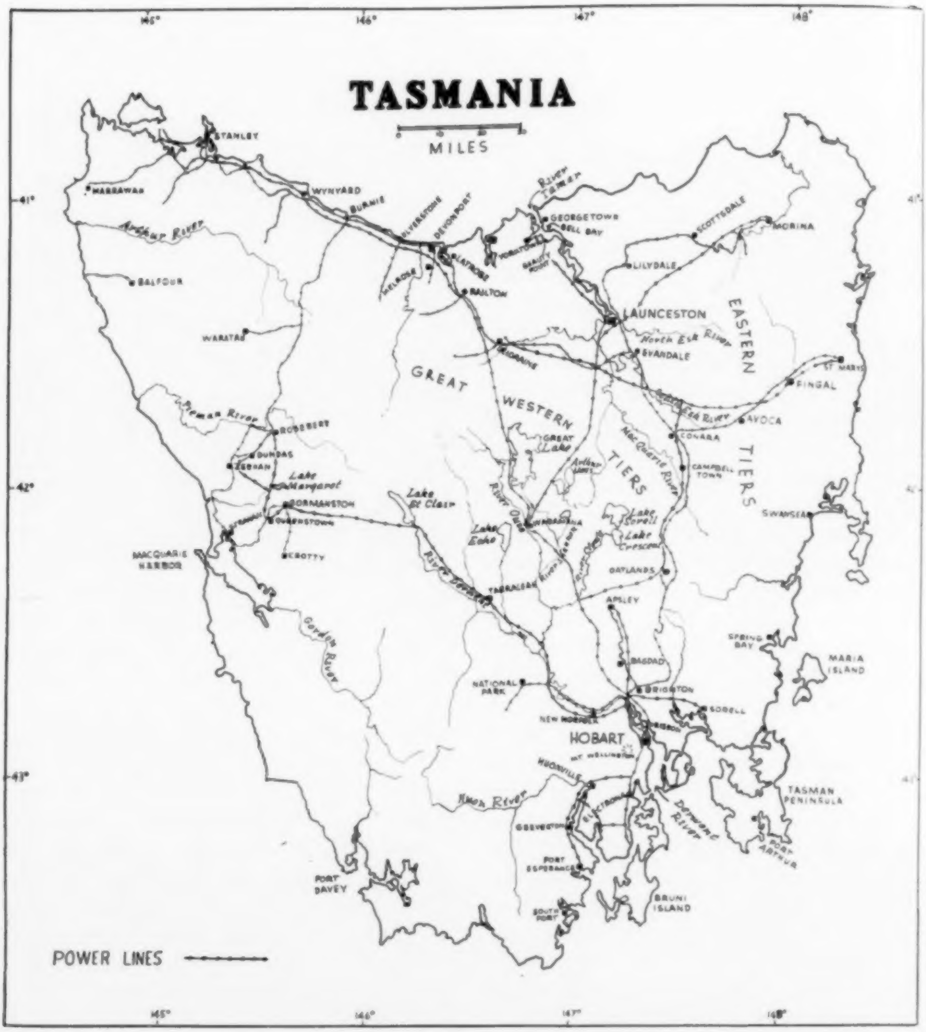

FIG. 1. LOCATION MAP OF TASMANIA

SHOWING THE PRINCIPAL PHYSICAL FEATURES, SETTLEMENTS, RAILWAYS AND POWER LINES.

is one of the most interesting aspects of Tasmania's occupation.

Occupation of the Hobart Site

In the initial occupation of Australia the British were not concerned primarily with colonization in the usual sense but rather with the creation of isolated centers to receive prisoners dispatched from the home country. When Sydney became "over-crowded" convict stations were established elsewhere along the coast. Tasmania, with its insular form and small extent (26,215 square miles) was especially suitable for penal colonies and it was used for such purposes until 1853, or long after most centers had been abolished on the mainland. The first half century of Tasmanian history was largely concerned with penal establishments and the second half century was much taken up with

FIG. 2. SMALL COVE ACROSS THE DERWENT RIVER
MARKING THE SITE OF THE ORIGINAL SETTLEMENT ATTEMPTED BY BOWEN AT RISDON.

FIG. 3. VIEW FROM BELLERIVE ACROSS DERWENT ESTUARY TO HOBART
THE SUBURBS OF HOBART SPREAD FOR SEVERAL MILES ALONG THE BASE OF MT. WELLINGTON.

FIG. 4. ACROSS COMMERCIAL DISTRICT OF HOBART TO MT. WELLINGTON
THE FOREGROUND CONSISTS OF RECLAIMED LAND ALONG THE MAIN WATERFRONT.

overcoming the effects of those institutions. Gradually and inevitably, however, emancipists, retired military men and free settlers created the substantial type of occupation which now characterizes both urban and rural portions of the state.

In 1803, John Bowen was commissioned by Governor King at Sydney to establish a small group of convicts and soldiers along the Derwent River in southern Tasmania. A site at Risdon Cove, 16 miles from the entrance of the drowned river course, was specified in the orders, largely on the basis of the favorable account of the location by the explorer Bass (Fig. 2). A town was to be laid out and farm land cleared by the convicts. Risdon Cove appeared at the time to be suitable for a small settlement, but its anchorage was lacking in depth, the fresh-water supply proved inadequate at times, agricultural land was scarce in the narrow valley, and hills interfered with even limited expansion of the settlement. Taking into account the physical limitations of the site and the character of the human materials, the failure of the establishment would now seem to have been inevitable.

In 1804, a detachment of prisoners and soldiers under the leadership of David Collins arrived at Risdon Cove after an unsuccessful attempt to create a settlement at Port Phillip on the north side of Bass Strait. The strategic importance of securing a hold on the strait between Tasmania and the Australian mainland was recognized as soon as Tasmania was proved to be a detached body of land in 1798.

The unsuitability of Risdon Cove for an extensive and permanent settlement was immediately recognized by Collins, who selected a site at Sullivan's Cove on the opposite side of the river and four miles nearer its entrance. The site lay at the foot of Mt. Wellington; extensive tracts of gently sloping land were available; timber and building stone were abundant; a mountain stream provided an ample flow of fresh water; and a deep anchorage was immediately available alongside a small island near the shore. By the end of the year the Risdon Cove settlement was abandoned and Hobart became the administrative center for the south half of the island (Fig. 3).

"The Camp," as it was commonly called, on Sullivan's Cove spread with-

out prescribed form along the margin of the bay and a short distance inland to a rivulet, the banks of which were bordered by a dense growth of brush and trees. Small boats and supplies were held in tents under heavy guard on the small island in the cove where unloading was easy and where they were relatively safe from plunderers. At low tide the island could be reached from the mainland along a connecting bar. A quarry was opened in a ledge of sandstone near the waterfront to provide foundation materials. Shells gathered from the waterfront were burned for lime. "Wattle-and-dab" huts with thatched roofs became the characteristic early house-type. The initial settlement consisted of about 250 individuals, but it was supplemented at irregular intervals by the arrival of convict ships (Fig. 4). In keeping with the maintenance of a prison camp merchant vessels were prohibited from entering the Derwent River. With the rapid increase in convict population at Hobart during the early years the problem of subsistence was at times a difficult one, according to the account of J. B. Walker in his "Early Tasmania."

In 1810 Hobart contained about 150 houses scattered irregularly over the site. On the occasion of Governor Macquarie's visit in 1811 he appointed surveyors to draw up a town plan on which he named the principal streets. Cancellation by the Colonial Office in 1813 of the order prohibiting vessels from discharging cargo in Australian settlements without first calling at Sydney promoted the development of commerce at Hobart. The adaptability of the Derwent estuary for overseas commerce was conclusively demonstrated at that early time (Fig. 5). Overseas mail for the entire island was normally received at Hobart, and that destined for northern centers was sent overland. An "improved" road

FIG. 5. NEWTOWN AND OTHER NORTHERN SUBURBS OF HOBART

SPREAD OVER THE ROLLING FOOTHILL BELT BETWEEN THE MT. WELLINGTON UPLAND AND THE DERWENT ESTUARY. SPLIT PALING FENCES, SIMILAR TO THE ONE IN THE FOREGROUND, ARE CHARACTERISTIC THROUGHOUT TASMANIA.

FIG. 6. GENERAL VIEW TO THE NORTH OVER PRESENT-DAY HOBART
SULLIVAN'S COVE CORRESPONDS WITH THE SITUATION OF THE PRINCIPAL WHARVES SHOWN AT THE EXTREME RIGHT. THE SITE OF RISDON IS AT THE FOOT OF A LOW MOUNTAIN MASS SHOWN IN THE CENTER DISTANCE AND ON THE OPPOSITE SIDE OF THE ESTUARY. THE DERWENT ESTUARY PENETRATES DEEPLY INTO THE LOWLAND AND PROVIDES MANY MILES OF ACCESSIBLE WATERFRONT FOR URBAN DEVELOPMENT.

connected Hobart with Launceston via the midland route as early as 1818. By 1821, Hobart possessed a population of 2,700 and 421 substantial houses, all fronting on regular streets, the pattern and names of which are preserved in the modern city (Fig. 6).

Occupation of the Launceston Site

Late in 1804, or shortly after the establishment of Collins at Hobart, an expedition was dispatched from Sydney under William Paterson to occupy a suitable site on the Tamar River in northern Tasmania. In fact, when Collins found the entrance to Port Phillip on the mainland side of Bass Strait to be unsuitable for a settlement, he considered seriously the immediate transfer of his group to the Tamar district. Chance rumors, however, as to the difficulty of entering the Tamar and the unfriendly attitude of the aboriginals probably were the determining factors in directing Collins to the easily navigable and better known Derwent instead. The prime purposes in the establishment of a post near the mouth of the Tamar were to forestall any attempt on the part of the French to occupy Bass Strait and to afford protection to English sealers against American interlopers among the channel islands.

The accidental grounding of Paterson's flagship on a shoal on the east bank of the river entrance led to the preliminary occupation of the nearby site of George Town. Sufficient water was available along with suitable timber for the construction of huts to house the expedition of nearly 150 persons. Some cultivation was attempted while a careful survey of the Tamar was in progress.

A site at the head of Western Arm soon attracted Paterson's attention. Two streams of fresh water, ample timber and proximity to the sea were its favorable qualities. Western Arm, however, was not navigable by large vessels, and agricultural lands were neither fertile nor abundant.

At the head of the Tamar estuary extensive tracts of rich pasture land were found with only scattered trees to interfere with cultivation of the fertile soil. The site was regarded as ideal for an agricultural settlement, and although it lay 42 miles inland the Tamar provided a highway to the sea (Fig. 7).

Contrary to one's expectation the site on Western Arm was selected for the new settlement. The choice can be justified only with the knowledge that the government was interested principally in the establishment of a military center near the coast at which a number of convicts could be quartered to advantage and not in the creation of an extensive self-sustaining free settlement.

The site of York Town was marked out for the erection of quarters and haste was made in order that the group, now increased to some 200 by the arrival of additional convicts, could be settled before the arrival of winter. A brief occupation of York Town merely emphasized the advantages possessed by the Launceston site and Paterson recommended that a town site be reserved and farm lands be made available to settlers. In March, 1806, Launceston became the headquarters for agricultural settlement in northern Tasmania. The 42nd degree of latitude served to divide Cornwall County in the north with Launceston as its administrative center from Bucks County in the south with Hobart as its chief settlement. York Town was essentially abandoned by 1810.

Although Launceston was in most respects admirably suited for settlement purposes, the need for a port near the mouth of the Tamar was repeatedly expressed. Only vessels of less than 12-feet draft could reach Launceston. Governor Macquarie visualized the agricultural future of Launceston but also believed that George Town was destined to become a great commercial port. With the approval of the Colonial Office given in 1814, the governmental headquarters of Cornwall County were removed to George Town in May, 1819, by which time the necessary buildings had been constructed.

The inconvenience of having governmental headquarters 40 miles away from the principal northern settlement at Launceston coupled with the loss of the attractive local market for produce provided by the garrison resulted in vigor-

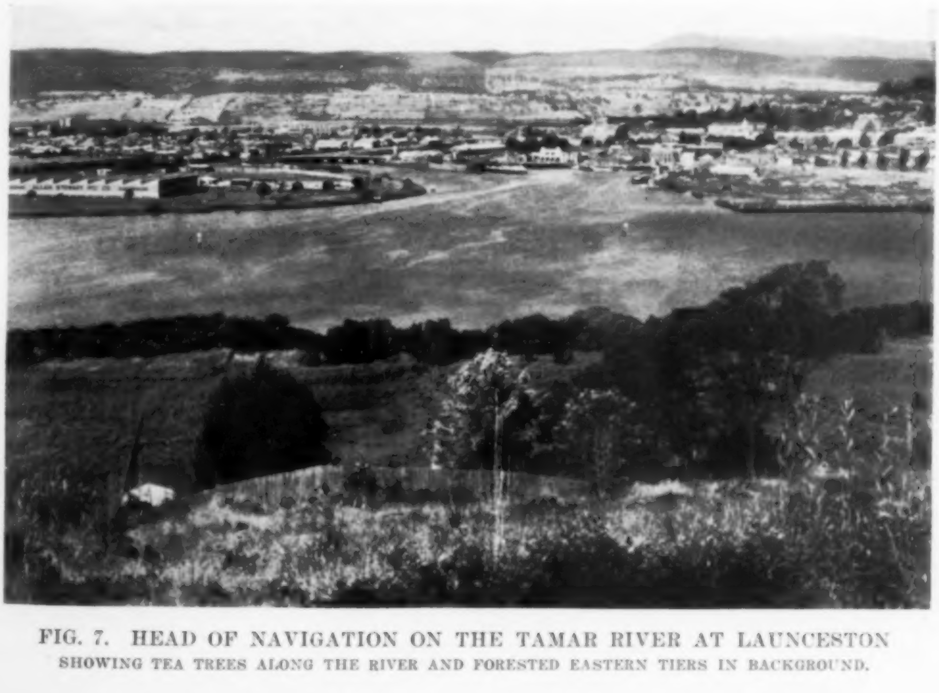

FIG. 7. HEAD OF NAVIGATION ON THE TAMAR RIVER AT LAUNCESTON
SHOWING TEA TREES ALONG THE RIVER AND FORESTED EASTERN TIERS IN BACKGROUND.

FIG. 8. A VIEW ACROSS THE PRINCIPAL RESIDENTIAL AREA
MOST OF LAUNCESTON LIES WITHIN A SMALL AMPHITHEATER OPENING UPON THE TAMAR RIVER.

ous objection to the new arrangement. In 1823, governmental authority for northern Tasmania was returned to Launceston. In the following years George Town lost in population and had little trade while Launceston enjoyed steady growth and an extensive business in wheat and wool shipped down the Tamar in vessels of 250 tons burden. Launceston served as the headquarters for the richest and most extensive agricultural district in the island, and by virtue of its position on a navigable waterway, became the principal focus of trade in the north of Tasmania (Fig. 8).

Early Rivalry Between Hobart and Launceston

Tasmania, with 27 per cent. of Australia's population, was constituted a separate colony from New South Wales in 1825 and Hobart was fixed as the seat of government. The inconvenience and delay involved in governing a colony so far removed from Sydney accounted for the early separation. Considerable opposition was presented at the time to the selection of Hobart as the capital of the new colony. The rapidly expanding agricultural settlement at Launceston especially objected to the location of government headquarters at the far south end of the island. Others emphasized the disadvantage of keeping the large convict population on the coast where escape was comparatively easy. New Norfolk and Brighton near the head of navigation on the Derwent River were proposed as better sites for the governmental and penal center, but established buildings and facilities at Hobart led to its continued choice. Hobart had a population of 5,000 by 1827 and conducted an increasing trade with Sydney, Great Britain and elsewhere.

Thus, the basic advantages of the Hobart and Launceston sites were early demonstrated, and from the two rival centers population, transportation routes and the various forms of land occupance spread into tributary valleys and lowlands. Sufficient contrast was present

in the potentialities of the two sites to make their later development complementary rather than merely competitive.

Rise of Industrial and Commercial Enterprises

One of the early industrial opportunities commanding attention in Tasmania was whaling. In spring the Derwent River is said to have "swarmed with whales." The first bay whaling station was built in 1806, and by 1841 the number had increased to thirty-five. In 1848, there were 37 whalers registered at Hobart employing 1,046 men. Many foreign whalers sought repairs and supplies in the quiet and deep waters of the Derwent. Launceston settlers operated whaling stations at Portland Bay and at Encounter Bay on the Australian mainland.

As an outgrowth of the whaling industry Hobart gained some prominence as a shipbuilding center, an abundance of suitable timber in the Derwent and Huon valleys facilitating that development. An export trade to the mainland was also developed in timber products, for Hobart was the natural shipping point for the rich southern timber region. Tasmanian hardwoods, because of their resistance to marine borers and decay, came into demand for harbor, railway and other construction purposes.

Wool production was early established in Tasmania on a commercial basis, and by 1830 the wool export from the island exceeded that from New South Wales. Generous grants of land by the early governors encouraged the pastoral industry. Massive wool stores of native sandstone were among the first large commercial structures to appear at Hobart and at Launceston (Fig. 9). Early recognition of the paucity of land resources in Tasmania, however, resulted in the migration of some persons with their flocks to Victoria, beginning in 1834. Melbourne itself was founded by such migrants in 1835. South Australia, likewise, drew immigrants and stock from overcrowded Tasmanian holdings.

During the period 1850–1880 Tasmania exported regularly large quantities of farm produce to Sydney and elsewhere. The California and Australia gold rushes created exceptional markets for Tasmanian agricultural and forest products during the 1850's and 1860's. The rural population of Tasmania became focused during those decades upon the more productive lands tributary to Launceston and Hobart.

By 1880, the mainland states of Australia had greatly expanded their agricultural industries and no longer depended on Tasmania for staple foodstuffs. Fortunately for Tasmania, the loss in agricultural markets was compensated by the discoveries between 1871 and 1882 of important mineral deposits, the exploitation of which provided large sources of income for several decades. The discovery of tin at Waratah in 1871 marked the opening of a new chapter in Tasmania's development. Later discoveries of valuable deposits of copper, zinc, lead, silver and gold were made in the western district at Gormanston, Rosebery, Balfour and elsewhere. Northern Tasmania and Launceston profited most from the mineral development because of direct railway connections with the mining districts.

The formation of the Australian Commonwealth in 1901 rendered more serious a number of problems which already faced Tasmania. Intensified competition with the richer mainland states and the application of Commonwealth economic policies, not recognizing fully the handicaps of the isolated position and the limited resources of Tasmania, have contributed to the static condition which has characterized most forms of economic activity in Tasmania in recent decades.

Emphasis on Specialized Agriculture

General agriculture and grazing ac-

FIG. 9. OLD GOVERNMENT WAREHOUSES AND RELATED STRUCTURES ALONG THE HARBOR MARGIN AT HOBART.

tivities in Tasmania have been on the decline for half a century or longer. In the 1850's Tasmania was regarded as the granary of Australia, and important wheat cargoes moved regularly to Sydney. In 1850 Tasmania had more sheep than it has to-day. Physical conditions and other factors have produced systems of agriculture which differ in many respects from those on the mainland.

Small areas are involved in Tasmania in comparison with the large wheat and sheep holdings of other states. Farm lands of good quality are widely scattered, which increases the transportation burden. General farming is characteristic of the island, but emphasis is usually placed on such specialty products as best suit the locality. Sharp and frequent contrasts in agricultural conditions coincide with abrupt changes in physiographic, climatic and soil conditions. Nearly half the island is wholly unoccupied by agriculture of any type. Machinery is much less utilized in Tasmania than in the more extensive farming areas on the mainland. Soil exhaustion and low crop yields reflect poor farm practices and the marginal character of much of the land.

The Midland, a lowland of varied relief and bordered by the abrupt margins of the Western and Eastern tiers, is Tasmania's principal pastoral and agricultural district. Extensive tracts of perennial rye grass and clover with scattered remnants of an open eucalyptus forest cover much of the rolling surface (Fig. 10). Most of Tasmania's wool and mutton is produced in that district. Midland flocks are driven to the bordering uplands after shearing is completed for summer pasturages as indicated by A. G. Lowndes and W. H. Maze in "The Land Utilization Regions of Tasmania."

Oats, lucerne, potatoes and peas are important crops in the flatter portions of the Midland and in areas of fertile soils derived from easily weathered basalt. Scattered small villages with stone houses of colonial design, old English farmsteads, fields bordered by hawthorn hedges, and extensive pasture lands comprise one of the most attractive landscapes in Australia.

Launceston and Hobart, occupying strategic positions on deeply penetrating estuaries to the north and south, command the trade of the Midland. Numerous wool stores are situated in close proximity to the wharves in both centers. Others are located along the

FIG. 10. VIEW TO EAST ACROSS THE TAMAR VALLEY NEAR LAUNCESTON USED FOR SHEEP AND OATS, WITH CHARACTERISTIC RAIL FENCES IN THE FOREGROUND.

railways entering those cities. Since overseas vessels are unable to reach Launceston, wool is lightered to Bell Bay and Beauty Point wharves near the Tamar mouth for foreign shipment. Direct contact with large wool carriers is made at Hobart, where neither tugs nor dredges are required in the operation and maintenance of the port.

Extensive public abattoirs at the margins of Hobart and Launceston process animals from the Midland and other districts for local consumption and for export. Increasing attention is being given to fat lamb production for export because it fits in well with general farming and forage production (Fig. 11). Pig raising, in similar manner, expands with the butter industry.

Ready access to the principal wheat-growing centers of the drier Midland area has likewise facilitated milling operations in both Launceston and Hobart. Hard wheat from South Australia is imported to blend with the softer local varieties.

Also tributary to Launceston is a belt of rich agricultural lands extending from the Tamar River northwest along the coast for a distance of about a hundred miles. The belt is 10 to 15 miles wide, and elevations of as much as 2,000 feet occur where it merges into the Central Plateau along its irregular southerly margin. Extensive tracts of red soils derived from fresh-water deposits and chocolate soils derived from basalt provide the principal bases for agricultural development. Most of the surface is hilly, and deep valleys have been cut through the basalt cover in places exposing poorer soil-forming materials.

The northwest coastal belt was never attractive to graziers because of its heavy forest cover, hence it was occupied only comparatively recently. The many small farm holders specialize in dairying and potato-raising. In 1935, the northwest coast produced potatoes on 30,000 acres of land which constituted five sixths of the land devoted to that crop. Potatoes from Tasmania are extensively used on the mainland and they rank as one of the most important crops in the island. Numerous small ports have arisen along the north coast to provide outlets for farm produce. All the west coast mining communities look to the north coast district for foodstuffs and other supplies, for the western half

of Tasmania is entirely unsuited for agriculture and grazing.

Tasmania has long held the position of the most important producer of export apples in the southern hemisphere. Although the area planted to apples is normally exceeded by those planted to hay, peas, potatoes and oats, the apple is easily the most valuable crop in Tasmania. It is more valuable than the Tasmanian wool clip and approximately equal to the value of all mineral production. Apple production ranks as one of the most successful phases of specialized farming.

About 2,500 growers, 78 per cent of whom have less than 15 acres of orchard, are engaged in the apple industry according to an official report on "The Tasmanian Apple Industry" by S. F. Limbrick. Probably 15,000 to 18,000 persons or almost 8 per cent. of the population of Tasmania are directly or indirectly dependent for their livelihood upon the industry. The apple industry in Tasmania occupies a position as important relatively as does wheat production in several mainland states. In 1935, the bearing acreage of apples amounted to 23,400 or slightly more

FIG. 11. APPLE ORCHARDS ALONG THE LOWER TAMAR RIVER
MARSH GRASS COVERS THE MUD FLATS BORDERING THE WATERWAY.

Local advantages of climate and soil in conjunction with the ability to provide fruit at a season opposite to the time of harvest in the northern hemisphere led to the beginning of specialized output of export apples about 50 years ago, especially in the Derwent and Huon valleys (Fig. 13). More recently production has spread to the Tasman Peninsula, Bagdad and Spring Bay districts in the south, as well as to the Tamar, Latrobe, Lilydale and Scottsdale districts in the north (Fig. 12). Many areas too rough for other forms of agriculture have proven to be excellent for orchards, while the higher slopes remain in eucalyptus forest.

than two thirds the total orchard plantings. During the past twenty years no large increase has taken place in apple plantings, which suggests that the industry has reached its economic limit under present conditions. However, large tracts of land remain which are suitable for apples should increased demands arise.

Shipments of Tasmanian apples to overseas markets have fluctuated between two and one half and three million cases in recent years. Hobart is the principal center of that trade, but Beauty Point and Bell Bay on the lower Tamar River handle increasing quantities of fruit grown in the northern dis-

FIG. 12. CHARACTERISTIC PASTURE LAND NEAR LAUNCESTON
WITH SCATTERED EUCALYPTUS TREES.

FIG. 13. THE KANGAROO RIVER VALLEY NEAR HOBART
DEVOTED TO APRICOTS, OATS AND PASTURE, WHILE BORDERING UPLANDS REMAIN IN TIMBER.

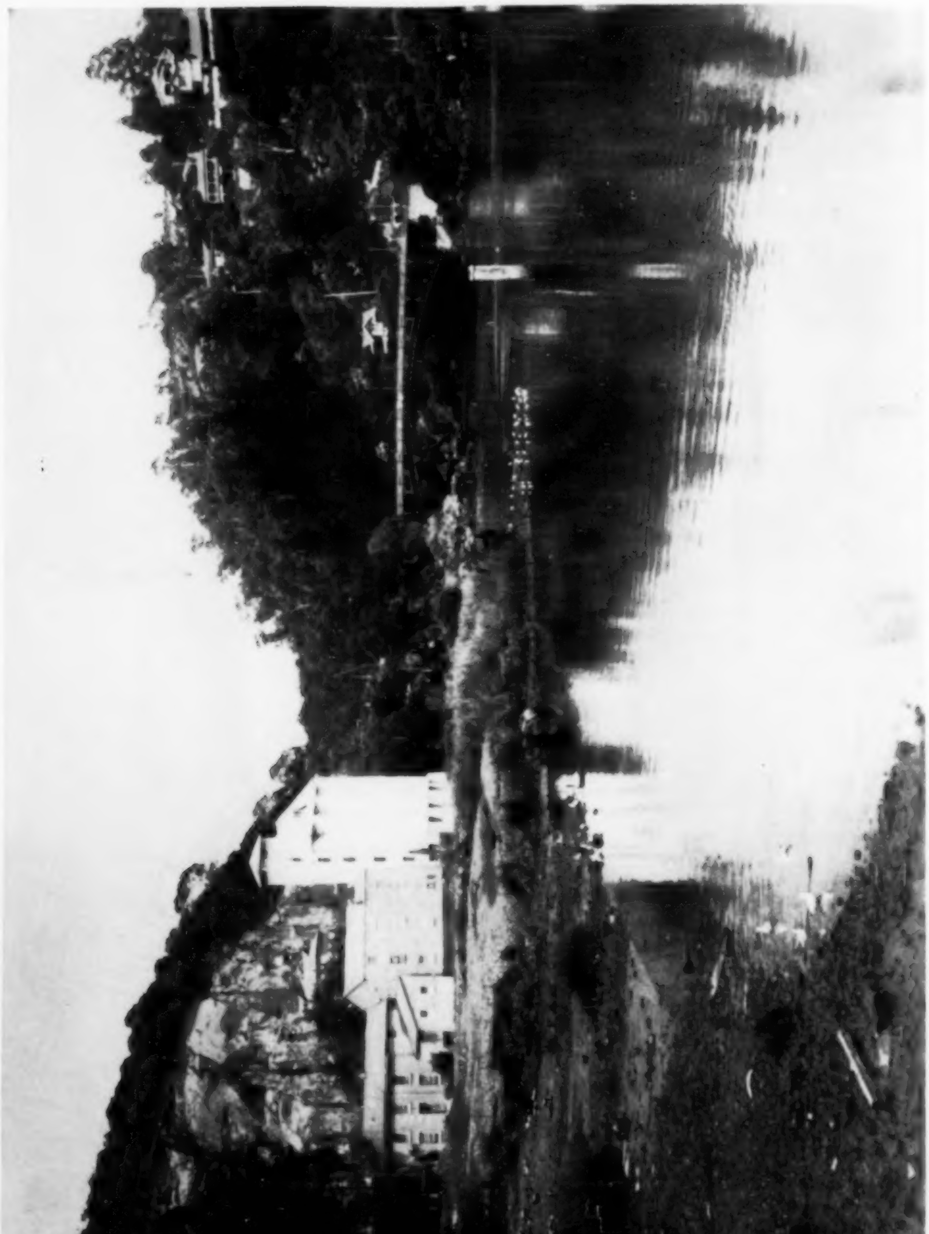

FIG. 14. GORGE OF SOUTH ESK RIVER AT LAUNCESTON

tricts. The shipping season for overseas export is relatively short, beginning in late February or early March and continuing until the middle of June. Apples are received at the export wharves by rail, river steamer and highway vehicles. As many as 300,000 cases may be shipped in a single week and on a peak day 100,000 cases may be handled over the wharves.

During the apple season many large vessels not normally calling at Tasmanian ports are diverted for that traffic. Interstate shipments are carried in smaller vessels plying regularly in coastwise trade, without refrigeration and over a longer season. They amount to about 1,250,000 cases annually. New South Wales and Queensland are the principal consumers of Tasmanian apples entering interstate trade, while the United Kingdom, Germany, Scandinavia, Holland and France have been the principal buyers overseas. In 1935, overseas markets took 72 per cent. of the shipments and interstate trade 28 per cent.

Pears are grown throughout the apple districts and occupy about 2,000 acres. Apricots, plums, cherries, peaches and quinces together occupy another 2,000 acres. Strawberries, raspberries, currants and other small fruits occupy 2,600 acres usually in close association with orchard districts. Preserved fruits, jellies and fruit pulp are important items moving in interstate and foreign trade from Tasmania.

Hydro-electric Power Stimulates Manufacturing

A half century or more ago small manufacturing industries were distributed among most of the settlements in Tasmania. Small breweries, tanneries, flour mills, farm implement shops, soap and candle factories, boot shops, basket works and wood-working shops utilized local raw materials and served home markets. The provision of railways tended to consolidate the many scattered and small plants principally in Hobart and Launceston. After the Commonwealth was established in 1901 the rise

FIG. 15. THE EXTENSIVE ELECTROLYTIC ZINC WORKS AT HOBART
ITS PRIVATE DOCK IS SHOWN TO THE LEFT ACROSS THE DERWENT RIVER.

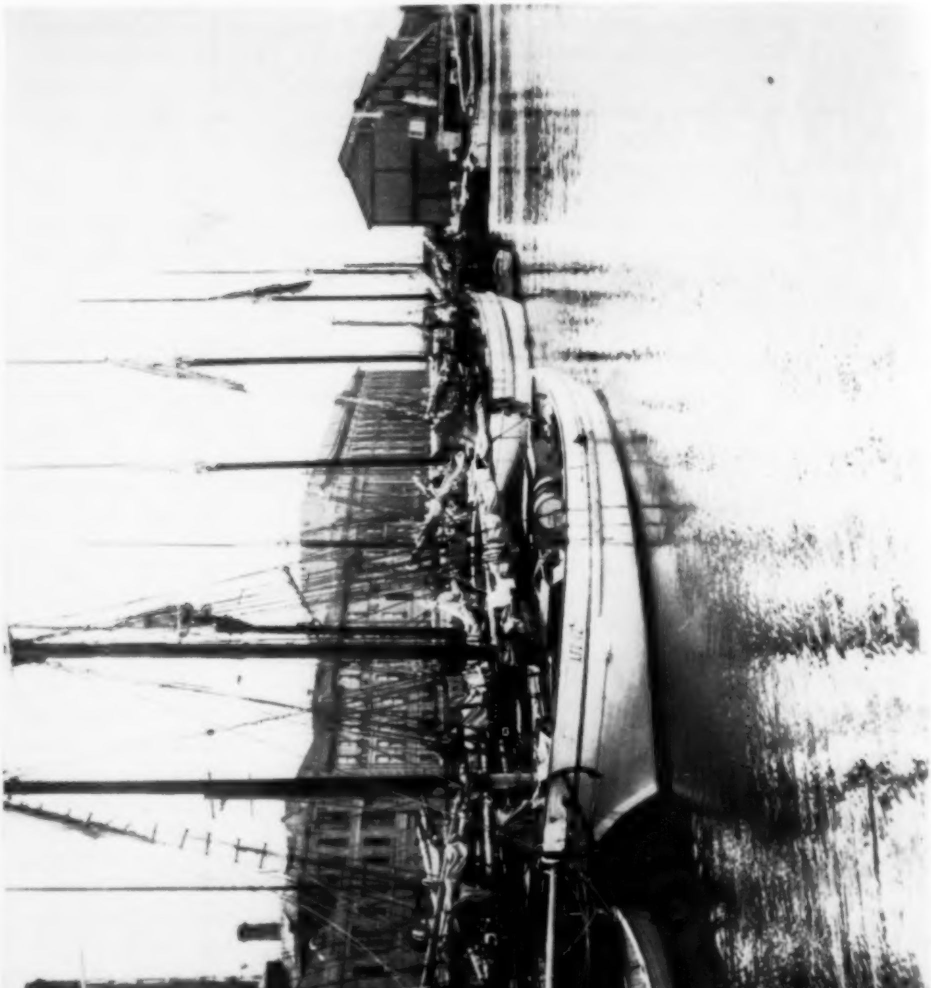

FIG. 16. A PORTION OF THE HOBART WATERFRONT BESIDE THE LARGE JAM FACTORY

MANY SMALL BOATS OF THE TYPES SHOWN ENGAGE IN LOCAL COMMERCE THROUGHOUT THE DERWENT RIVER DISTRICT AS WELL AS IN OTHER PARTS OF TASMANIA.

of large-scale manufacturing plants on the mainland brought about a decline of most forms of manufacturing in Tasmania.

During the past two decades, however, Tasmania has made important progress along manufactural lines largely as a result of the provision of abundant and cheap hydro-electric power. More than 90 per cent. of the power now used in industries is hydro-electric energy. Hobart and Launceston have been vitalized by the new source of power. While Tasmania compared unfavorably with several other states in the possession of usable coal, it now boasts of the best supply of hydro-electric power in Australia. The utilization of that valuable resource has only begun and much more power can be developed as soon as it is demanded. There is the possibility that hydro-electric power may in the future provide the means of attracting many more industries to Tasmania, permit a further expansion of population, and rejuvenate agriculture by the creation of larger local markets. But cheap electrical power has not yet attracted a sufficient number of new industries to bring about a great change in economic conditions in Tasmania. Other obstacles, such as limited local markets, high transportation costs and restricted supplies of many raw materials, discourage extensive manufactural development.

The Central Plateau or Lake District is the principal source of hydro-electric power and the outstanding physiographic feature of Tasmania. It consists of an undulating diabase plateau 3,000 to 4,000 feet above sea-level and sloping gently southeastward. On the north and northeast precipitous escarpments called the Great Western Tiers define its border; on the west its margin is deeply furrowed by west-flowing rivers forming extremely rugged mountain ranges; and on the south the Derwent River and its tributaries have converted the margin of the plateau into a jumbled mass of valleys and hills. A rainfall of 30 to 60 inches annually characterizes much of the upland surface. Most of the lakes occupy shallow basins and are bordered by insignificant uplands. Most of the plateau is covered by stunted eucalyptus forest and coarse grass, but dense growths of evergreen beech and horizontal brush characterize the west margin.

In 1908, the Tasmanian Government granted a private company permission to develop water power at Great Lake for the treatment of complex zinc ores by electrolysis. After the work was well advanced the company met financial reverses, and, in 1914, the project was acquired by the government. By 1916, the work was completed and power was delivered to Hobart. Thus was begun the extensive modern state hydro-electric system in Tasmania (Fig. 1).

Storage for the Great Lake power project consists of the natural lake, the capacity of which was increased by means of a 40-foot multiple-arch dam to 1,150,000 acre-feet. The surface of the lake (60 square miles) is 3,350 feet above sea-level and 1,125 feet above the power house at Waddamana. An additional water shed of 107 square miles was added to the Great Lake water shed of 153 square miles by diversion of the headwaters of the neighboring Ouse River. Installed capacity of the Waddamana power station is 66,000 horse power. High-voltage transmission lines extend to Hobart (63 miles distant), to Launceston (53 miles) and to Railton (59 miles). Smaller distribution lines radiate from those centers. Most parts of Tasmania lie within a 90-mile radius of the Great Lake power plant, thus greatly facilitating the distribution of power.

Several smaller power sites have been developed by the Hydro-electric Commission, and their output is fed into the state-wide system of power lines. Lake

FIG. 17. LARGE MODERN WOOLEN MILL AT SOUTH MARGIN OF LAUNCESTON

FIG. 18. BRISBANE STREET IN THE COMMERCIAL CORE OF LAUNCESTON

St. Clair is the source of water for developing 21,000 horse-power at Tarraleah, and it is claimed to afford an ultimate capacity of 126,000 horse-power. The River Shannon contributes 15,000 horse-power to the state system.

Several privately owned power supplies have been developed in the west coast region to serve mining interests. For example, mines at Gormanston and smelters near Queenstown obtain 10,000 horse-power from the Lake Margaret development. The Lake Margaret scheme has a catchment area of only eight square miles, but a well-distributed rainfall of 145 inches and an effective head of 1,150 feet for the turbines are highly favorable factors. Mines at Waratah also have small independent hydro-electric sources. A number of cities operate small water power plants along the north coast. Launceston has one of the oldest installations in the Commonwealth in the South Esk River gorge near the city (Fig. 14).

Principal Industries Attracted by Cheap Power

The electrolytic zinc refinery, established in 1917 at Hobart, is the largest and most important manufacturing establishment in Tasmania (Fig. 15). It utilizes 45,000 continuous horse-power drawn from the state hydro-electric system. Some 800 men are employed in the plant, which operates on a continuous basis. The daily capacity of the works is 150 to 200 tons of electrolytic zinc, most of which is cast into 50-pound slabs and is shipped by water to world markets. Small amounts of rolled zinc and other products are also manufactured. Fuels (coal and coke) are imported by water from New South Wales. An important by-product of the plant is sulfuric acid, which is used to treat phosphate rock obtained from Nauru and Ocean islands. About 20,000 tons of superphosphate fertilizer are produced annually, which amount is sufficient to meet Tasmania's needs. The recovery of sulfur by-products from ore-roasting processes is of great national significance, for other sources are unavailable in Australia. Contact with the state railway system makes possible the direct distribution of fertilizer materials to most developed parts of the island. At some future time atmospheric nitrogen may be fixed with Tasman hydro-electric power, thus providing Australia with a second essential fertilizer material.

The zinc concentrates treated at Hobart are obtained from Broken Hill, N.S.W., mines after roasting plants at Port Pirie, Wallaroo and Adelaide, S.A., and Cockle Creek, N.S.W., have extracted most of the sulfur. Vessels returning from Hobart carry residue ore materials containing small quantities of lead, silver, cadmium and copper for final treatment at Port Pirie. Although the zinc plant is situated 4 miles above Hobart and 16 miles from the entrance to the Derwent estuary, a natural depth of more than 30 feet of water is available at the company docks. Zinc ores from mines at Rosebery and other centers on the west coast of Tasmania also have been treated at various times. Those ores are moved by rail to Zeehan for milling and roasting, thence to Strahan for shipment by water to Hobart. Their complex nature, low grade and great depth have combined to make extraction uneconomical in recent years. Launceston at one time was a smelting center for ores obtained from scattered mines in the northeast portion of the island. Metal mining is on the wane in Tasmania, but it was an important factor in the island's development especially during the period 1880–1910.

Another industry, situated along the estuary margin 12 miles south of Hobart, which owes its establishment to cheap hydro-electric power, and using 4,500 horse-power, is the carbide works at Electrona. Large portions of the

carbide and electrode requirements of Australia are manufactured in that modern industrial town. Raw materials are quarried locally and the plant has direct ocean shipping facilities.

A third major new industrial plant at Hobart, owing its establishment to favorable power conditions, but also to suitable climatic, transportation, labor and marketing conditions, is the large confectionery and chocolate factory at Claremont, 8 miles north of Hobart. The plant is situated on a peninsula jutting into the Derwent River and it is served by a private wharf. An attractive residential suburb has been developed on the adjoining mainland. The confectionery plant is a good example of the type of branch plants recently established in Australia by British manufacturers.

Two large jam and fruit-canning plants, one situated on the waterfront at Hobart and the other at Newtown (a northern suburb), provide an outlet for large quantities of fruits and berries grown in the vicinity (Fig. 16). Preserved fruits and jams are one of the important export items to Great Britain from Hobart. The focal position of Hobart with respect to numerous valleys adapted to fruit-growing facilitates large-scale preparation of highly perishable fruits and berries. Both water and land types of transport serve in the assembly of the fruits from scattered small farm units.

Plans for the establishment in the vicinity of Hobart of a large paper-manufacturing plant are well matured. Australia has long been dependent upon Canada for most types of paper because of her inability to make satisfactory grades from eucalyptus and other native hard woods. It appears that suitable processes have now been developed, and Tasmania, with considerable forest land resources, cheap power and water transport, may become an important source of paper for the entire Commonwealth. A second plant is projected for the north coast at Burnie.

At Launceston two important woolen mills utilize hydro-electric power but also credit favorable climatic and labor conditions for their establishment. One mill is situated in the elevated southern residential district (Fig. 17), while the other is located on the Tamar River lowland near the shipping docks and in close proximity to wool warehouses and northern residential suburbs. Blankets, velours, tweeds and knitting wools are manufactured for Australian markets. Both mills are branch plants of large British textile manufacturers.

Several ceramic plants in Launceston utilizing local clays find outlet for their products in Tasmania and in mainland markets. Native blackwood (*Acacia melanoxylon*) is used in the manufacture of fine furniture and novelties which have become as characteristic of that state as are the Mulga wood products of the mainland. Being the center of the Tasmanian railway system the principal repair shops are located at Launceston.

At Railton, to the west of Launceston, is a cement plant utilizing local raw materials and serving markets in Tasmania and on the adjacent mainland. A quarter million tons of limestone are quarried annually at Melrose and shipped through Devonport for blast furnace use at Newcastle and Port Kembla, N.S.W. Large quantities of electrical power are utilized by both of those industries.

Most of Tasmania's coal mines are situated in the Fingal district about 40 miles southeast of Launceston. As many as 125,000 tons are produced annually or a sufficient amount to serve most of Tasmania's needs. The railways are the principal consumer utilizing nearly half the annual output. Small amounts of coal are imported for the manufacture of gas and for metallurgical establishments. Hydro-electric power is made

available even to the towns in the coal-producing district, thus illustrating its wide distribution and its strong competitive ability.

Growing Importance of the Tourist Industry

The economic value of the growing tourist trade is recognized clearly in Tasmania. An active government tourist bureau maintains offices in all the capital cities of the mainland to promote travel to the island. Many of the conditions discouraging to agriculture and industry are favorable to the tourist trade. The generally irregular surface with altitudes up to 5,000 feet, the little altered character of much of the island with large tracts scarcely inhabited, the succession of beaches interspersed with rugged promontories, the rich native vegetation, the scores of lakes and streams, the pleasantly cool and moist climate, the variety of agricultural landscapes ranging from expansive sheep stations to intensively cultivated horticultural communities, restful towns and small cities with architectural types reminiscent of old England and a rich historical background recalled by structures still in evidence everywhere are some of the recreational attractions afforded by Tasmania. The island is only 16 hours by steamer from Melbourne and 44 hours from Sydney, thus attracting large numbers of persons even during short holiday periods. Most of the tourists come from the capital cities of the mainland, and they find the Hobart summer a pleasant relief (Fig. 18). The Christmas-New Year's holiday period marks the height of the summer tourist season. Winter sports are also being stimulated during June, July and August in an attempt to spread the tourist season over the entire year. The small size of the island and the extension of motor roads to supplement existing railways enable the visitor to see a wide variety of landscapes in a relatively brief period. In addition to the long-established midland route between Launceston and Hobart new scenic highways now extend along the east coast and over the central plateau. A national reserve of about 200 square miles and including mountain-bordered Lake St. Clair is generally recognized as the most scenic attraction in the island. Mountains reaching elevations of 4,000 to 5,000 feet, dense forests, deep canyons, waterfalls and lakes attract many visitors. Winter sports as well as summer attractions are available there.

Conclusion

Whether due to luck or foresight the early selection of Hobart and Launceston as the principal centers of occupation in Tasmania was fully justified by the later rise to importance of those centers. Although Tasmania's population is more evenly distributed geographically than that of any other Australian state the dominance of the Hobart and Launceston agglomerations is the outstanding characteristic of population distribution.

Although an integral part of the Australian Commonwealth, Tasmania comprises a somewhat small and isolated section with a lesser supply of good land and other natural resources to hold its slowly expanding population. Greater opportunities on the mainland attract Tasmanian youth as well as foreign capital. Tasmania continues chiefly to export raw materials and to import manufactures, although the development of cheap hydro-electric power has brought about a partial reversal of those movements. In some phases of specialized agriculture and in the growing tourist industry Tasmania finds important sources of income and a basis for friendly cooperation with other states of the Commonwealth.

THE FUTURE OF THE SOCIAL SCIENCES

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I

The question of what can be expected from the social sciences always comes to the front in times like the present. The reason for this interest in the future possibilities of sciences of human relation is, I suppose, obvious. Every one agrees that whatever other troubles the advancement of science may have brought in its wake, it has released us from some age-long fears and insecurities. The natural sciences have undoubtedly given us a large measure of control over many of our traditional enemies, although we may not always exercise this power.

Even when we can't do anything directly about averting natural events, science is still invaluable in two principal ways: First, science forewarns us of certain events and thus enables us to avoid their more serious consequences. If rain is predicted we carry an umbrella. Ships are warned that a hurricane is likely to follow a certain path. We may protect ourselves from certain diseases by proper inoculations; and so forth. In the second place, the mere possession of scientific knowledge and scientific habits of thought regarding the natural universe relieves us from a world of fears, rages and other unpleasant dissipations of energy. Scientific knowledge operates as a sort of mental hygiene in the fields where it is applied. If the morning paper reports an earthquake, an eclipse, a storm or a flood, these events are immediately referred to their proper place in the framework of science, in which their explanation, *i.e.*, their relationship to other events, has already been worked out. Hence each new event of this character calls for very little, if any, "mental" or "emotional" strain upon the organism so far as our intellectual adjustment to it as an event is concerned.

Political and social upheavals, on the other hand, such as wars, revolutions and crime are to most people a matter of shock and much personal recrimination and other emotionalism. The point is perhaps best illustrated by a recent cartoon showing two old gentlemen with obviously high blood pressure engaged in animated conversation. The venerable wife of one of them appears and says, "Remember now, the doctor says you must not talk about Mr. Roosevelt." The nervous condition of most commentators on the European situation is not, I think, conducive either to the clearest kind of analysis of that upheaval or to good digestion. Floods, hurricanes and crop failures also worry us, but we take a very different attitude toward them.

It is not surprising, therefore, that man should have become increasingly interested in the question as to whether this same tool called science might do as much for him as regards his social predicaments. But immediately certain apparently insurmountable obstacles present themselves, which send all but the hardiest scurrying for shelter in the tents and pagodas of the traditional doctors of social ills—the magician, the soothsayer, the priest and the politician, with their lore. What are these obstacles to the development of an effective social science? Are they as insurmountable as they seem?

II

In order to avoid the accusation that I am merely attacking a straw man by

selecting only the more silly of the objections that have been urged against the possibilities of a science of human relations, I shall deal instead with those that are held by responsible scientists themselves. That is, I shall omit entirely certain metaphysical questions which have traditionally beclouded the subject, such as the question of free will, God, etc. What I am about to say will be quite compatible with any view one wishes to hold on these subjects. In short, I do not think they are questions of scientific importance. Posit, if you like, free will not only for man but for all other things in nature. All I am interested in at present is to point out the great regularity and predictability with which men will things. The same may be said for God. He is clearly a being with remarkably and demonstrably regular habits. It is this regularity and predictability of the will of both men and gods that is of interest to science.

There are, on the other hand, the doubts which are advanced by competent scientists, such as Julian Huxley. In a recent address before the American Association for the Advancement of Science under the title of "Science Natural and Social,"[1] he discusses what seems to him to be major obstacles in the path of the social sciences. It is true that he already leans heavily toward the position of the present paper. The reservations which he feels are inherent in the nature of the subject-matter and the situation that confronts the social scientists are therefore deserving of the highest respect and most careful consideration. Yet after such consideration I do not feel that these obstacles are of the fundamental nature that Mr. Huxley is inclined to assign to them. Let us examine the case.

Mr. Huxley begins with somewhat the same question with which I started: He says:

> The question immediately poses itself as to why the emergence of social science into large-scale and efficient operations has been so long delayed. The triumphs of natural science both in discovering radically new knowledge and in applying it practically to satisfy human needs have been so spectacular and so fruitful that it would seem natural and obvious to extend the same methods to the field of social phenomena.
>
> The answer is a very simple one: the methods are *not* the same. The scientific spirit remains unaltered whether it is contemplating a nebula or a baby, a field of wheat or a trades union. But the methodology of social science is inevitably different from that of natural science. It is different and must be different from one basic reason—the investigator is inside instead of outside his material. Man can not investigate man by the same methods by which he investigates external nature. He can use the methods of natural science to investigate certain aspects of man—the structure and working of his body, for instance, or the mode of his heredity; but that is because these are shared with other organisms and because they are partial aspects which can be readily externalized. But when he starts investigating human motive, his own motives are involved; when he studies human society, he is himself part of a social structure.
>
> What consequences does this basic difference imply? In the first place, man must here be his own guinea pig. But this is impossible in the strict sense, for he is unable to make fully controlled experiments [pp. 6, 7].

The basic difference between the social and the physical sciences is here alleged to be that in social science "the investigator is inside instead of outside his material." This is incidentally one of the most frequently heard clichés, which is supposed to be so self-evident as to require no analysis. Will it bear analysis? I think not at all. It turns out on examination to be little more than a figure of speech designed to call attention to the danger of biased observations and interpretation—a danger which is present in all science and which can in any case only be circumvented or reduced through the use of scientific instruments and methods of procedure which are part of scientific training in *any* field.

When an anthropologist goes to a remote savage tribe to study its social behavior, why is he any more inside his

[1] SCIENTIFIC MONTHLY, January, 1940.

material than when he studies a colony of anthropoid apes, beavers, ants, the white rats in the laboratory, an ecological distribution of plants or, for that matter, the weather, the tides or the solar system? At what point exactly in this series does the mysterious transition from outside to inside of one's material take place? Nor do I admit that I have to go to a distant land and study savages in order to make my point. I can give as objective and checkable a report on some of the social events that take place in the community where I now live as I can on the meteorological events that take place there. Both involve problems of observing and reporting accurately the events in which I am interested. In doing this, I need to use instruments as far as possible to sharpen my observation, to check it and to report it accurately. These instruments do not exist ready-made in any field. They have to be invented. They may be quite elementary as yet in much social investigation, consisting of little more than a pencil, a schedule, a standardized test or the recording of an interview. But we also have at our command the movie camera with sound equipment with which social behavior can be observed in its cruder aspects with the same accuracy as any physical behavior is observed. When I use these instruments I am no more "inside" my material than when I photograph an eclipse.

The invention of units and instruments with which to systematize observation is part of the scientific task in all fields. Neither calories nor calorimeters came ready-made in the phenomena of physics. They have to be invented to apply to the behavior in question, just as units of income or standard of living and scales for measuring them have to be invented. I am not making light of the difficulties involved in inventing either such units or appropriate instruments of scientific observation. Nor would I minimize the problems of interpreting the data which I observe. But here again I have at my disposal the same rules of logic, statistics and scientific method that I apply to observations of physical events.

To be sure, Mr. Huxley makes the concession that we can use the methods of natural science "to investigate certain aspects of man—the structure and working of his body, for instance, or the mode of his heredity." But clearly these are not the proper subject-matter of the social sciences at all. Huxley appears here to be under the common misapprehension that anything pertaining to man is necessarily subject-matter for social science. It hardly needs to be remarked that man, as such, is as much the subject-matter of biology, physiology, chemistry or physics as he is the subject-matter of the social sciences. Only certain aspects of man's behavior is the subject-matter of the social sciences. What some of the more difficult of those aspects are in Mr. Huxley's opinion is betrayed in the very next statement: "But where he [the social scientist] starts investigating human motives," he says, "his own motives are involved; when he studies human society, he is himself a part of a social structure." And what is supposed to be so important about this? "In the first place," says Mr. Huxley, "man must be his own guinea pig." He then proceeds to repeat the familiar objection about the difficulty of controlled experiment in the social sciences.

A great many able people apparently share Mr. Huxley's feelings regarding the mysteriousness, the uniqueness and the inscrutability of human motives. To begin with, we may note that motives are not directly observed phenomena at all, but are inferences from behavior. How do we, as a matter of fact, determine them right now? One common method is to assemble twelve good men and true, farmers, bookkeepers, salesmen—anybody that comes to hand, subject them to a mass of evidence regard-

ing the circumstances of a certain event, after which the judge charges them to determine whether "the motive" of one of the principals in the affair was fraudulent, felonious, malicious, etc., or not. And how do these worthy citizens proceed with the assignment? They draw on their own lives and experience, on what their random and unsystematic observation of human behavior in the past has taught them, plus what they may have learned from folklore, the Bible and perhaps books on history, psychology and psychoanalysis. Against this background they lay the testimony, and on this basis they decide "the" motive. The procedure is far from perfect, as we know, and it is not claiming too much, I believe, to assert that scientists properly trained for this kind of work would make much fewer mistakes. But we think highly enough of even the ability of the lay jury to determine human motivation to make their decision the basis of life or death for free citizens.

"When the scientist studies human motives," says Huxley, "his own motives are involved; when he studies human society he is himself a part of a social structure." I submit that the only motive of a true scientist in trying to determine the motive of an action is to find the true answer to the question, and that is the only motive with which scientists both physical and social are concerned, *as scientists.* In short, the motive of the sociologist and the physicist are exactly the same in the face of a scientific problem. *The motive is to find an answer that meets the requirements of a scientific answer.* The fact that the social scientist has always been a part of a social structure is no more a handicap to its objective study than is the fact that he is also part of the physical universe which he studies. Error, corruption and bias, conscious and unconscious, are constant dangers inherent in *all* observation, both physical and social. The training of a scientist consists of developing in him the traits of character as well as technical skill, and the use of corrective instruments to reduce to a minimum the errors that beset our unchecked senses in every field.

With respect to the difficulty of laboratory experimentation in the social sciences, we may grant a great deal to Mr. Huxley's point, especially as regards comparisons with such sciences as chemistry, physics and biology. But the difficulty is by no means insuperable. Extensive sociological experiments involving laboratory observations of children have been and are being carried on. Motion picture and sound recording of these experiments, furthermore, permit their detailed and repeated study. Nor are experiments on actual communities impossible. Stuart C. Dodd, for example, carefully measured with instruments especially constructed for the purpose the hygienic status of a group of isolated Syrian villages.[2] He divided the villages into two samples for experimental purposes. One sample was then subjected to a two-year period of hygienic education through an itinerant clinic. At the end of this period the hygienic status of the two samples, consisting of one experimental village and three controls, were again carefully measured. The comparison of the scores of the experimental and the control villages yielded a reliable measure of the results of the program of health education. It is true that in this case the absence of contact of these villages with the influences of the outside world was a principal condition of the success of the experiment. But the study will stand for a long time as a model of scientific proficiency in the care with which the measuring instruments were prepared, tested and applied, as well as in the attention to problems of sampling and probable errors.

Finally, it should be pointed out that

[2] "A Controlled Experiment on Rural Hygiene in Syria." Oxford University Press, 1934.

the matter of laboratory control varies greatly with different sciences. The solar system has never been brought into any laboratory. Astronomical laboratories do contain very ingenious symbolic and mechanical representations of the astronomical aspects of that system and remarkable instruments for observing it. These every science must unquestionably develop. Beyond this, the question of laboratory conditions becomes one of convenience and mechanical ingenuity. Statistical devices which permit the observation of two or more variables while the influence of others are held constant, in the sense of their influence being measured and allowed for, are already in common use. In justice to Mr. Huxley, it should be said that he recognizes this fact. In dealing with the multiplicity of causation in social situations he says:

> In regard to multiple causation we may look forward to an extended use of techniques of mathematical correlation. These have already been developed to a high pitch for dealing with problems of multiple causation in physical science, and special methods have been worked out by Spearman and his school for dealing with psychological questions. The use of probability methods is also indicated. Here again these have been developed to a high pitch for use in natural science. . . . In one field, that of the straw ballot, it is developing such uncanny accuracy that it is infringing upon practical politics [pp. 8, 9].

In short, we may say with respect to laboratory experimentation in the social sciences, first, that it is by no means impossible, and secondly, that it is not entirely essential because the same results can be secured by statistical methods.

III

We have now considered two very common and apparently crucial differences between the social and the physical sciences, namely, (1) the notion that in the former the scientist is in some mysterious way part of his data and (2) the difficulty of laboratory experimentation. Mr. Huxley goes on to say:

> Finally, there comes the most fundamental difference of all. Values are deliberately excluded from the purview of natural science: values and all that they connote of motive, emotion, qualitative hierarchy and the rest constitute some of the most important data with which the social scientist must deal. But how can science deal with them? Science must aim at quantitative treatment: how can it deal with the irreducible absolutes of quality? Science must be morally neutral and dispassionate: how can the social scientist handle the ethical bases of morality, the motives of passion?
>
> Let us be frank with ourselves. There is a sense in which, because of the qualitative difference between its data and those of natural science, social science can never become fully and vigorously scientific. To understand and describe a system involving values is impossible without some judgment of values, and still more impossible without such value-judgments is the other scientific function, that of control [p. 8].

These sentiments have been so widely and uncritically repeated that they are accepted by a great many able people, including scientists, as in the nature of self-evident facts. It requires, therefore, a certain temerity to express the opinion that there is little foundation for these assumptions. I believe they owe their prevalence to the prestige of the sources that have repeated them and the frequency and emotionality of their repetition, rather than to their tenability in the light of critical analysis.

Let us consider this mysterious word "value." John Dewey in one of his recent publications gives the following account of how it happens that the problem of value arose as a separate problem:

> The elimination of value-conceptions from the science of non-human phenomena is, from a historical point of view, comparatively recent. For centuries, nature was supposed to be what it is because of the presence within it of *ends*. In their very capacity as ends they represented complete or *perfect* Being. All natural changes were believed to be striving to actualize these ends as the goals toward which they moved by their own nature. Classic philosophy identified *ens*, *verum*, and *bonum*, and the identification was taken to be an expression of the constitution of nature as the object of natural science. In such a context there was no call and no place for any *separate* problem of valuation and values, since what are now termed values were taken to be integrally incorporated in the very

structure of the world. But when teleological considerations were eliminated from one natural science after another, and finally from the sciences of physiology and biology, the problem of value arose as a separate problem.[3]

The principal thing to note in this statement is that the problems of value, ends and purposes were once also prominent in the physical sciences. Most of them now manage to get along without the concept, in the sense here under discussion. We manage to keep the matter alive in the social sciences by a quaint habit of speech by which the verb "valuating," meaning any discriminatory or selective behavior, is converted into a noun called "values." We then go hunting for the things denoted by this noun. But there are no such things. There are only the valuating activities we started with. What was said above about "motives" applies with equal validity to values. They are clearly inferences from behavior. That is, we say a thing *has* value or *is* a value when people behave toward it so as to retain or increase their possession of it. It may be economic goods and services, political office, a mate, graduation, prestige, a clear conscience or anything you please. Now since valuations or values are empirically observable patterns of behavior, they may be studied as such, by the same general techniques as we use to study other behavior.

As a matter of fact, everybody is more or less regularly engaged in such study of other people's values. It is quite essential to any kind of satisfactory living in any community. We try to find out as soon as possible what the values of our neighbors are. How do we find out? We observe their behavior, including their verbal behavior, listen to what other people say about them, what they spend their money for, how they vote, whether they go to church and a hundred other things. On a more formal and scientific level, straw votes on men and issues are taken to reflect the values of large groups. Economists, of course, have been studying for years certain kinds of evaluations of men through the medium of prices. There appears to be no reason why values should not be studied as objectively as any other phenomena, for they are an inseparable part of behavior. The conditions under which certain values arise (*i.e.*, the conditions under which certain kinds of valuating behavior take place) and the effects of "the existence of certain values" (as we say) in given situations are precisely what the social sciences must study and what they are studying. These values or valuating behaviors, like all other behavior, are to be observed, classified, interpreted and generalized by the accepted techniques of scientific procedure. Whence then derives this notion that they represent a unique and insurmountable obstacle in the social sciences?

I have suggested that the basic reason is a confusion of words with things—a very common source of confusion in the social sciences. The point is well illustrated in the passage I have quoted from Huxley. "Science must be morally neutral and dispassionate," he cries: "How can the social scientist handle the ethical bases of morality, the motives of passion?" Well, what kind of "handling" of these things does the scientific quest call for? Huxley says, I think correctly, that science must be morally neutral and dispassionate. Is it really impossible for a trained social scientist to go into a community and give a true report on what are the ethical bases and the morals of a community? The question seems to me quite preposterous. The laws, the mores, the customs, the etiquette, the education and the general behavior of people have been so studied repeatedly and are surely as amenable to such study as is a study of the social life of ants and termites. It is true that the reliability and validity of the results of such study depend upon

[3] "Theory of Valuation," *International Encyclopedia of Unified Science* (1939), pp. 2, 3.

the technique with which they are carried out. But that is equally true of the observation and reporting of observation in the other sciences. Of course, it makes a difference, as we have seen, whether a poll is carried out by the technique of a Gallup or a *Literary Digest*. I am not here minimizing the difficulties of objective study of human behavior, a point to which I shall return later. I am saying that if we take the proper precautions of the kind that constitute scientific training in any field, including the development of instruments to facilitate these precautions, there appears to be no reason why a reliable report of the ethical codes and practices of people can not be determined as has indeed repeatedly been done by anthropologists and sociologists in recent decades.

It will perhaps be objected that I have avoided the statement that "to understand and describe a system involving values is impossible without some judgment of values." The only judgment of values I am compelled to make in studying the mores of a community is the judgment of what behavior is relevant to my problem. That is a value judgment which every scientist has to make regardless of what he is studying. If Huxley's statement that "to understand and describe a system of values is impossible without some judgment of values" means that I must also appraise the things I observe from the standpoint of my own moral standards, then his statement is certainly preposterously false. I can certainly report the bald fact that a certain tribe kills its aged and eats them without saying one word about the goodness or badness of that practice according to my own standards, or allowing these standards of mine to prevent me from giving an accurate report of the facts mentioned. The only value judgment which any properly trained scientist makes about his data are judgments regarding their relevance to his problem, the weight to be assigned to each aspect and the general interpretation to be made of the observed events. These are problems which no scientist can escape, and they are not at all unique or insuperable in the social sciences.

It is interesting to note that Huxley himself, after having made the sweeping and eloquent statements I have quoted, rather comes around in the very next paragraph to the viewpoint I have taken. Referring to the objection which I quoted a moment ago, he says: "However, this is not quite so serious as at first sight appears. Even in natural science, regarded as pure knowledge, one value-judgment is implicit—*belief in the value of truth*." This value judgment, together with the value judgments as to what facts and methods are relevant to this end, are, as I have already said, undoubtedly involved in the social sciences. But they are no less involved also in all other sciences.

There remains, therefore, only the question as to whether the *application* of the knowledge which constitutes, or would constitute, a mature social science, does not involve value judgments of a type which the other sciences do not require. That the application of scientific knowledge (*i.e.*, problems of social control) involve value judgments is obvious. The only question is whether this is a problem peculiar to the social sciences. Here again Huxley concludes, and I think correctly, that this problem is equally present in the other sciences. After we know how to produce dynamite and what it will do, there remains the question: Shall we drop it from airplanes to destroy cathedrals and cities, or shall we use it to build roads through the mountains? After we know the effects of certain drugs and gases, the question still remains: Shall we use them to alleviate pain and prevent disease or shall we use them to destroy helpless and harmless populations? There is certainly nothing in the well-developed sciences

of chemistry or physics which answers these questions. Neither is it, in my opinion, the business of the social sciences to answer directly the question of what form of government we should have, what our treatment of other races should be, whether we should tolerate or persecute certain religious groups, whether and to what degree civil liberties should be maintained, and a multitude of other questions which agitate us. What, then, are social scientists for and what should they be able to do?

Broadly speaking, it is the business of social scientists to be able to predict with high probability the social weather, just as meteorologists predict sunshine and storm. More specifically, social scientists should be able to say what is likely to happen socially under stated conditions. A competent economist or political scientist should be able to devise, for example, a tax program for a given country which will yield with high probability a certain revenue and which will fall in whatever desired degrees upon each of the income groups of the area concerned. Social scientists should be able to state also what will be the effect of the application of this program upon income, investments, consumption, production and the outcome of the next election. Having devised such a tax program and clearly specified what it will do, it is not the business of the social scientist any more than it is the business of any other citizens to secure the adoption or defeat of such a program. In the same way competent sociologists, educators or psychologists should be able to advise a parent as to the most convenient way of converting his son into an Al Capone as well as how to convert the boy into an approved citizen, according to what is desired.

My point is that no science tells us what to do with the knowledge that constitutes the science. Science only provides a car and a chauffeur for us. It does not directly, as science, tell us where to drive. The car and the chauffeur will take us into the ditch, over the precipice, against a stone wall or into the highlands of age-long human aspirations with equal efficiency. If we agree as to where we want to go and tell the driver of merely the goal of our journey he should be able to take us there by any one of a number of possible routes the costs and conditions of each of which the scientist should be able to explain to us. When these alternatives have been made clear it is also a proper function of the scientist to devise the quickest and most reliable instrument for detecting the wishes of his passengers. But except in his capacity as one of the passengers, the scientist who serves as navigator and chauffeur has no scientific privilege or duty to tell the rest of the passengers what they should want. There is nothing in either physical or social science which answers this question. Confusion on this point is, I think, the main reason for the common delusion that the social sciences, at least, must make value judgments of this kind.[4]

It does not follow, of course, that science by virtue of its true function, as outlined above, may not be of the utmost importance in helping people to decide intelligently what they want. As a matter of fact, the broad general wants of people are perhaps everywhere highly uniform—for example, a certain physical and social security and some fun. It is disagreement over the means toward these ends as represented by fantastic ideologies that result in conflict and chaos. I have pointed out that in proportion as a science is well developed, it can describe with accuracy *the consequences* of a variety of widely disparate programs of action. These consequences, if reliably predicted, are bound, of course, strongly to influence what people will want. But it remains a fact that

[4] See, for example, "Industrial Conflict" (Cordon, 1939), Editor's Foreword and Chapter 1.

science, in the sense of a predicter of consequences, is only *one* of the numerous influences that determine an individual's wants and his consequent behavior.

As social science develops and secures recognition of its authority, however, there is every reason to believe that science will become a major influence in determining the wants of men as well as the means of satisfying them. By charting reliably the remote as well as the immediate consequences of the various possible courses of action, men's wants will be modified accordingly. In this way, science and scientists might be major influences in *determining* value judgments. The knowledge which constitutes science obviously already exerts this influence in some fields. When the social sciences attain maturity and respect, we shall no longer waste our energies in following the vain hopes of early and permanent salvation proffered by various ideologies which to-day seduce a large number of social scientists as well as the masses of men from more fruitful activities.

IV

So far I have dealt mainly with the obstacles which are alleged to prevent the social sciences from ever attaining the stature and functions already exercised to a large degree by other sciences. Since the future of the social sciences is obviously determined largely by the seriousness of these obstacles, I have deemed it proper to deal at some length with them. I have not tried to minimize these problems in the sense of overlooking the long and painstaking labor which their solution doubtlessly involves. I have merely suggested that these prolems are soluble by the same general methods to which similar obstructions in other fields have yielded. At this point the question naturally arises: Has any progress been made in this direction? What are the achievements, if any, of the social sciences thus far which warrant the optimistic view I have taken?

Any comprehensive review of the present status and achievements of the social sciences is obviously beyond the scope of the present discussion. Although I think it is unquestionably true that the social sciences have made, during the present century, more actual progress in the direction I think they must go than they made in all preceding history, it would be absurd to pretend that this progress is, as yet, reflected to any great extent in our management of social affairs. Scientific information of a more or less reliable character is more widely diffused than ever before, but the scientific mode of thought has obviously made very little headway. Practically no one approaches the major social problems of the day in a spirit of disinterested scientific study. The idea that these problems are to be solved, if at all, by the use of instruments of precision in hands that do not shake with fear, with anger or even with love,[5] does not seem to have occurred even to many people who pass for social scientists. They have joined the journalist and the soap-box crusader in the hue and cry of the mob. Their supposedly scholarly works bristle with assessments of praise and blame, personalities and verbal exorcisms which have no place whatever in the scientific universe of discourse. Not only do these verbomaniacs pass in the public eye as great social scientists of the day, but they not infrequently presume to patronize honest scientists who stay with their proper tasks of building a science and the instruments by means of which any difficult problems are to be solved.

But behind this fog, this dust storm of books about the inside of this political movement, the private life and morals of its leaders and the treatises on democracy, substantial work is going on. Men are patiently accumulating data about human behavior in a form which in the

[5] *Cf.* R. L. Duffus, *Harper's*, December, 1934.

fullness of time will permit a type of generalization which has never before been possible. Some are engaged in the undramatic but fundamental work, basic to all science, of classifying the multitudes of human groups and behavior patterns as a first step toward the formulation of generalizations regarding them. Still others are pioneering in the construction of actuarial tables from which may be predicted the probable degrees of harmony to be expected from intimate personal relationships of an almost universal type. Still others are experimenting with the invention and perfecting of instruments for the more accurate and precise observations and recording of social phenomena. It is easy to point to the flaws in these instruments as it was easy to point to flaws in the early microscopes and telescopes. But without these beginnings and the patient centuries of undramatic labor, sciences like bacteriology could not have appeared at all. Finally, there are those, and they are the most suspect of all, who are experimenting with and inventing new systems of symbolic representation of phenomena. New adaptations of mathematics by which otherwise hopeless complexities can be comprehended are quite fundamental but do not lend themselves to popular display. The work of Leibnitz, Faraday and Hertz was not the popular science of their day. Yet it is by virtue of their strange calculations with strange symbols that men to-day fly and broadcast their speech around the earth.

If I deal primarily with these more obscure and undramatic labors of social scientists, it is because I regard them as more important in the long run than the conspicuous contemporary achievements which are common knowledge. I do not overlook or underestimate these more obvious and demonstrable achievements. The transition in our time to more humane treatment of children, the poor and the unfortunate by more enlightened education, social work and penology must, I think, in large measure be attributed to the expanding sciences of psychology and sociology. I know, of course, that whenever a war or a depression occurs journalists and preachers point to the impotence of economists and political scientists either to predict or prevent these disasters. The fact is that the course of events following the World War, down to and including the present, were predicted with great accuracy by large numbers of social scientists. That nothing was done about it is not the special responsibility of social scientists. It is the common responsibility of all members of a community, including scientists, and especially of those who specialize in mass education, mass leadership and practical programs.

But it is not my purpose to review the past and present achievements of the social sciences. I am concerned primarily with their probable future. Even if I should admit that social scientists are to-day merely chipping flints in the Stone Age of their science, I do not see that we have any choice but to follow the rough road that other sciences have traveled. The hope of arriving at a comparable success may seem remote, and the labors involved may seem staggering. But is the prospect really unreasonably remote? Suppose that some one four hundred years ago had delivered an address on the future of the physical sciences and suppose that he had envisioned only a small fraction of their present achievements. What would have been the reaction of even a sophisticated audience to predictions of men flying and speaking across oceans, seeing undreamed-of worlds, both through microscopes and telescopes and the almost incredible feats of modern engineering and surgery? Nothing I have suggested, I think, in the way of mature social science with comparable practical application seems as improbable as would the story of our prophetic physicist of four hundred or even one hundred years ago.

But what about the costs of such a pro-

gram? What price must we probably pay for a social science of a comprehensiveness and reliability comparable to some of the better developed physical sciences? The costs are undoubtedly considerable, and it remains to be seen to what extent humanity is willing to pay them. What are some of the principal items both as regards material and psychological costs?

The mention of costs suggests that I am about to digress into the subject of allocations of funds in university and other budgets. The advancement of science undoubtedly does involve costs of this type, but I shall not go into them because I am at present more concerned with other types of costs which have nothing to do with money or with budgets. Let me therefore dismiss the question of monetary costs with a brief estimate by Huxley in the article I have already quoted: "Before humanity can obtain on the collective level that degree of foresight, control and flexibility which on the biological level is at the disposal of human individuals, it must multiply at least ten-fold, perhaps fifty-fold, the proportion of individuals and organizations devoted to obtaining information, to planning, to correlation and the flexible control of execution." Even this may seem staggering to educators who are wondering how to maintain merely their present activities. Unquestionably this program will call for readjustments in our present national economy. But how does the entire expenditure for scientific research in the universities of the land compare with the price of a single battleship? The endowment for social science research in 16 leading universities totals only $3,000,000, or an average annual income from endowment per institution of about $7,500.[6] Suppose the current census will cost 40 million dollars. A battleship costs about twice as much. The British, we are told, are spending for war purposes alone almost $20,000,000 per day.[7] Perhaps it will occur to some future generation to try a reallocation of such funds. If so, Huxley's proposal will be readily financed. But are we or some future generation likely to change so radically our notions of what is worth while spending money for? This brings us face to face with costs of science which come perhaps higher, and touch us more deeply, than any of its financial costs.

First of all, the advancement of the social sciences would probably deprive us in a large measure of the luxury of indignation in which we now indulge ourselves as regards social events. This country, for example, is enjoying at present a great emotional vapor-bath directed at certain European movements and leaders. We believe to-day apparently that the assassination of Hitler would quite solve the problems of Europe, just as we believed twenty years ago that hanging the Kaiser would achieve the same end. Such projects minister to deep-seated jungle-fed sentiments of justice, virtue and a general feeling of the fitness of things, as compared with what a scientific diagnosis of the situation indicates. In short, one of the principal costs of the advancement of the social sciences would be the abandonment of the personalistic and moralistic interpretation of social events, just as we had to abandon this type of explanation of physical phenomena when we went over to the scientific orientation.

Closely related and indeed inseparably connected with the necessary abandonment, in science, of personalistic and moralistic types of explanation is the necessity of abandoning or redefining a large vocabulary to which we are deeply and emotionally attached. Concepts like freedom, democracy, liberty, independence, free speech, self-determination and a multitude of others have never

[6] The Rockefeller Foundation. "A Review for 1939," p. 42.

[7] A. Comstock, *Events*, May, 1940, p. 349. The estimate is from the report of the Chancellor of the Exchequer to the House of Commons, March 13, 1940.

been realistically analyzed by most people as to their actual content under changing conditions. Any such analyses, furthermore, are sure to seem like an attack upon these cherished symbols and the romantic state of affairs for which they stand. As every social scientist knows, these are subjects that had better be handled with care. We like to think that there are not as yet any storm troopers lurking in our colleges to drive out an Einstein. In the meantime our own storm troopers, no less the agents of a self-constituted political hierarchy masquerading under the guise of religious servants, achieve exactly the same result with respect to Bertrand Russell. Social sciences worthy of the name will have to examine realistically all the pious shibboleths which are not only frequently the last refuge of scoundrels and bigots, but also serve as shelters behind which we to-day seek to hide the facts we are reluctant to face. The question is, how much pain in the way of disillusionment about fairly tales, disturbed habits of thought and disrupted traditional ways of behaving will the patient be willing to put up with in order to be cured of his disease? He will probably have to become a lot sicker than he is before he will consent to take the medicine which alone can save him.

Finally, the advancement of the social sciences will cost the abandonment not only of *individual concepts* carried with us from prescientific times. It will require us also to abandon deeply cherished *ideologies*, resembling in form if not in content their theological predecessors. The notion of some final solution, preferably in our own generation, of the major social problems that agitate us is a mirage which even scientists have great difficulty in abandoning. Many of them still confuse the social sciences with various cults, religions and political dogmas. Only last year, for example, twelve hundred American scientists signed a manifesto declaring among other highly laudable sentiments that in their opinion "in the present historical epoch, democracy alone can preserve intellectual freedom." If this was intended merely as a rhetorical expression of sympathy for the unfortunate and persecuted in other lands, I know of no decent person who would not gladly join them in such an expression. If, however, they want this statement to be taken literally as a scientific conclusion arrived at by the accredited methods of science, then these scientists have allowed their sympathies to overcome their judgment and have rendered a disservice to science by identifying it with a political dogma, namely, that state of affairs to which some of us are accustomed and which we happen to like.

I know of no scientific evidence whatever to indicate that democracy, or any other single system of social or political organization, is the *sole* system under which science can prosper. All that I can find any *scientific* warrant for is that under some conditions, democracy, defined in any constant way you please, is compatible with a certain degree and type of intellectual freedom. As for the main issue, every one with even a superficial knowledge of the history of science must know that some of the most notable triumphs of science occurred under régimes making no pretentions to democracy. Even to-day (1938–1939) three Nobel Prizes for science go to Italy and to Germany. To be sure, we also hear of attacks upon Einsteinian physics in Germany. We conveniently forget that the first truly popular democratic movement in Europe found "no use for scientists" and forthwith beheaded the father of modern chemistry. We conveniently forget that only a few years ago several states, under the leadership of American statesmen, passed laws against the teaching of evolution. These things *do occur* also in democracies. I would condemn them *wherever* they occur. I am opposed to making science the tail of *any* political kite whatsoever. Political systems have

changed, and they will change. Science has survived them all.

The mere fact that I, personally, happen to like the democratic way of life with all its absurdities, that I probably would find some current alternatives quite intolerable, and that I may even find it worth while to die in defense of democracy of the type to which I am accustomed, are matters of little or no importance as touching the scientific question at issue. My attachment to democracy may, in fact, be of *scientific* significance chiefly as indicating my unfitness to live in a changing world. To accept this simple notion is perhaps a cost of social science that few are prepared to pay.

Finally, what does the future promise for social scientists in the way of freedom to perform the tasks which I have outlined as their proper business? Here again, we need not expect to escape the troubles which other scientists have encountered throughout history. Chemists and physicists from time to time have suffered persecutions because of the conflict of their findings with more generally accepted views. They have continued to hew to the line, however, until to-day they enjoy a certain immunity and freedom of investigation which social scientists do not share. Why do physical scientists enjoy this relative security in the face of changing political régimes, and how may social scientists attain a corresponding immunity?

The answer is popularly assumed to lie, as I noted in the earlier part of my remarks, in the peculiar subject-matter with which social scientists deal. I doubt if this is the principal reason. I think a far more fundamental reason for the relative precariousness of the social sciences lies in their comparative incompetence.

Social scientists unfortunately have failed as yet to convince any considerable number of persons that they are engaged in a pursuit of knowledge of a kind which is demonstrably true, regardless of the private preferences, hopes and likes of the scientist himself. *All* sciences have gone through this stage. Physical scientists are, as a class, less likely to be disturbed than social scientists when a political upheaval comes along, because the work of the former is recognized as of equal consequence under any régime. Social science should strive for a corresponding status. Individual physicists may suffer persecution, but their successors carry on their work in much the same way. If social scientists possessed an equally demonstrably relevant body of knowledge and technique of finding answers to questions, that knowledge would be equally above the reach of political upheaval. The services of *real* social scientists would be as indispensable to Fascists as to Communists and Democrats just as are the services of physicists and physicians. The findings of physical scientists at times also have been ignored by political régimes, but when that *has* occurred, it has been the *régime* and not the *science* that yielded in the end.

What impresses me is the trivial effect of political interference upon the well-developed sciences. I recognize, of course, the frequently unfortunate effect of these movements upon individual careers and individual projects. But if we plot the course of scientific advance during the past two hundred years, the impressive fact is how little its main course has been deflected by all the petty movements of so-called "social action," including the major political revolutions. The demonstrable superiority of science as a method of achieving *whatever* men want has caused even its persecutors to return to it, after only very temporary and local crusades, chiefly against individual scientists.

I have emphasized that physical scientists are indispensable to any political régime. Social scientists had better work toward a corresponding status. Already some of them have achieved it to a degree. I venture to believe, for

example, that qualified social statisticians have not been and will not be disturbed greatly in their function by any political party. Their skill consists in the ability to draw relatively valid, unbiased and demonstrable conclusions from societal data. *That* technique is the same, regardless of social objectives. No régime can get along without it. It is the possession and exercise of such skills alone that justifies the claim of academic immunity. To claim it for those who insist on taking for granted that which needs to be demonstrated can only result in the repudiation for everybody of the whole principle of academic freedom. For the same reason, we had better not become so devoted to blatant crusades for academic freedom that we forget to bolster the only foundation upon which academic freedom can ever be maintained in the long run, namely, the demonstrated capacity of its possessors to make valid and impersonal analyses and predictions of social events.

My conclusion is that the best hope for the social sciences lies in following broadly in the paths of the other sciences. I have not tried to minimize the difficulties that beset these paths. I have merely argued that they are not insurmountable, and that in any case we really have no choice but to pursue this one hope. For we are already so heavily committed to the thoughtways and the material results of science in so large a part of our lives that we can not either go back or stand still. In short, the trends that have been strikingly evident in the social sciences in recent decades will, I believe, continue at an ever more rapid rate. Social scientists will talk less and say more. They will rely ever more heavily on a more economical type of discourse, namely, the statistical and the mathematical. Much of what now passes for social science will be properly relegated to other equally honorable departments, such as journalism, drama or general literature. As such, this material will have its uses as propaganda, news, art and a legitimate outlet for the emotions of men. Indeed, nothing I have said regarding the possibilities of scientific study of human affairs should be interpreted as in any way contemplating an abandonment or a restriction upon the artistic, religious, literary or recreational arts which also minister to the cravings of men. I have on the contrary rather advocated that the social sciences had better not handicap themselves by aggrandizing to themselves roles which they can not fulfil.

Scientists had better confine themselves, I have argued, to three tasks: First and foremost, they should devote themselves to developing reliable knowledge of what alternatives of action exist under given conditions and the probable consequences of each. Secondly, the social scientist should as a legitimate part of his technology, as well as for its practical uses, be able to gauge reliably what the masses of men under given circumstances want. Finally, he should in the applied aspects of his science develop the administrative or engineering techniques of satisfying most efficiently and economically these wants, regardless of what they may be at any given time, regardless as to how they may change from time to time and regardless of the scientist's own preferences.

Thus the social sciences of the future will not pretend to dictate to men the ends of existence or the goals of striving. They will merely chart the possible alternatives, the consequences of each and the most efficient technique of arriving at *whatever* ends man shall from time to time consider it worth while to pursue. If the social sciences devote themselves effectively to this role, they have a future of unlimited possibilities and have nothing to fear from the changes that will doubtless occur in the future as they have occurred in the past.

CHRISTOPHER WREN, F.R.S.

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In a general information test Wren's name would be associated immediately with architecture and perhaps with churches. Yet how many people to-day know when he lived or anything more of him than that he was the architect of St. Paul's Cathedral in London? Were they to be told that he has been responsibly named as "possibly the greatest Englishman after Shakespeare"[1] their astonishment would probably be great. This paper, therefore, presents some of the evidence for Wren's greatness as reflected in his achievements in science, and indicates the remarkable promise of the first third of his life before he became absorbed in his architectural labors, magnificent as these were.

Christopher Wren was born in England in 1632 and died early in 1723 in the ninety-first year of his life. This great span of life is in itself notable, for in the seventeenth century life expectancy was short. A man of sixty was old, and few indeed attained ninety years of age. Furthermore, Wren's old age did not lessen his mental powers nor slacken his physical strength unduly, for he remained active in his office as surveyor-general of the royal works until 1718 and was responsible for the repair of Westminster Abbey until his death five years later. Yet this long life was lived by a man whose youth had been too sickly for him to be sent to school except for a short time. His biographer (either his son or his grandson, for the "Parentalia" does not reveal which of the two wrote the various parts of the Wren papers published in 1750) comments on this:

> As to his bodily constitution, it was naturally rather delicate than strong, especially in his youth, which seemed consumptive; and yet, by a judicious regularity and temperance, (having acquir'd good knowledge in physick) he continued healthy, with little intermission, even to this extreme old age. Further, 'tis observable, that he was happily endued with such an evenness of temper, a steady tranquility of mind, and christian fortitude, that no injurious incidents, or inquietudes of human life, could ever ruffle or discompose; and was in practice a stoick.[2]

Another writer described him thus:

> As to his person, he was low of stature, and thin; but by temperate and skilful management (for he was a proficient in anatomy and physic) he enjoyed a good state of health, and his life was protracted to an unusual length. . . . He died as he lived, with great calmness and serenity, and little other sickness.[3]

Other notable facts about this great span of life are that Wren lived during six reigns, those of Charles I, Charles II, James II, William and Mary, Anne and George I, as well as through the Commonwealth, and that he held office under five of these rulers without interruption. Wren was a boy of ten when civil war broke out, and a student at Oxford at seventeen when Charles I was tried and beheaded. Nine years later he was kept out of his lecture room at Gresham College in London when soldiers under the Lord Protector seized the college for a barracks. His friends and relatives were among the political prisoners of those decades of war and revolution. He lived through the plague year of 1665, and from the fire of 1666 came his great opportunity: the rebuilding of the City of

[1] H. A. L. Fisher, as quoted by John F. Fulton, *Yale Jour. of Biol. and Med.*, p. 315. March, 1931.

[2] "Parentalia, or Memoirs of the Family of the Wrens . . . chiefly Sir Christopher Wren, . . . compiled by his son Christopher, now published by his grandson Stephen Wren, Esq.," p. 346. London, 1750.

[3] John Ward, "Lives of the Professors of Gresham College," pp. 105, 106. London, 1740.

London. The Revolution of 1688 apparently did not affect his task of rebuilding other than to further it through the sympathetic, interested support and the excellent taste of Queen Mary. Nor for a time at least did the change to the Hanoverian dynasty cause him to lose royal favor. Not until 1718 did a jealous cabal, so it is stated, force him out of office and into retirement after fifty years of service under royal appointment.

Wren's first royal recognition of importance came soon after the restoration of 1660 from Charles II, that lover of clever men and beautiful women. Charles II placed Wren on a commission to solve the problem of how to preserve and restore the greatly dilapidated and neglected Cathedral of St. Paul's. Before any plans could be carried out the great fire swept through the City. At once Charles appointed Wren surveyor-general for the rebuilding of the City, though he did not accept Wren's masterly plan for the rebuilding of the burned area on a new and improved scheme. Robert Hooke was his assistant to supervise the building by private owners; but Wren himself was responsible for the building of St. Paul's Cathedral and fifty-one parish churches, two theaters and various other public structures. In addition, as surveyor-general of the royal works from 1669 to 1718, with the official responsibility for the upkeep and oversight of all the royal palaces and their subsidiary parts, he planned and built, among others, a large part of Hampton Court and Winchester palaces, Chelsea College and Royal Greenwich hospitals. Before his public work had become so overwhelming, in the 1660's and early 70's, Wren had already been the architect for the Sheldonian Theater in Oxford, the great library of Trinity College, Cambridge, and the Chapel of Emmanuel College, Cambridge. He had also made a survey of Salisbury Cathedral in 1669 for his friend Seth Ward, Bishop of Salisbury. All this he did under each succeeding ruler through five reigns without regard to religious or political differences.

The story of these various buildings is in itself a notable one, reflecting not only Wren's genius as an architect but his tact and skill in dealing with kings and craftsmen, churchmen and poets, his integrity of character in insisting on solid foundations and honest workmanship, and a devotion to the public service that made him refuse all pay for his services in connection with the building of the Royal Greenwich Hospital for sick and pensioned sailors and their dependants, and that made him take a salary of only two hundred pounds a year for all the time St. Paul's was being rebuilt. A contemporary called Wren an English Vitruvius. Truly it can be said of him: he found London built of wood and clay; he left her built of brick and stone.[4]

But to return to Wren, the scientist and fellow of the Royal Society. When he was knighted by Charles II in 1674 Wren chose as the motto for his coat of arms "Numero, Pondere et Mensura," a reference to the verse in the Book of Wisdom (11:20): "But by measure and number and weight Thou didst order all things." Thus he registered his lifelong devotion to mathematics. Very early in his life this interest appeared and was fostered by the lessons of his brother-in-law, Dr. William Holder, himself a person of many accomplishments. His first recorded invention, an astronomical instrument, was made in 1645 when he was only thirteen years old and was soon followed by an instrument for planting grain, "A rustick thing" . . . he wrote "which shall plant corn equally without want and without waste."[5] Before he was sixteen he had translated into Latin the section "on Geometrical Dialling" in Oughtred's "Clavis Mathematicae" with

[4] "Parentalia," p. 324, 336.

[5] *Ibid.*, pp. 182, 183.

such success that Oughtred in his preface to the "Clavis" wrote of Wren as:

a young man of marvelous gifts, who when not yet sixteen years of age, advanced astronomy, gnomonics, statics and mechanics by his distinguished discoveries, and from then on continues to advance these sciences. And truly he is the kind of man from whom I can shortly expect great things, and not in vain.[6]

Already the lad was the "darling of mathematicians,"[7] well on his way to become, as Newton acknowledged later, one of the three foremost geometers of Newton's time.

After a short stay in Westminster School and some further time as an assistant to Dr. Charles Scarborough as demonstrator for his public lectures on anatomy, Wren went to Oxford where he was recorded a gentleman commoner at Wadham College in 1649.[8] He probably went there earlier, however, for he was granted his B.A. in 1650, his M.A. in 1653. He was at once elected fellow of All Souls. He continued to live at Wadham College until summoned to London by appointment to the professorship of astronomy at Gresham College in 1657. Wadham College was then enjoying the most illustrious period of its history under the wardenship of Dr. John Wilkins, himself a lover of men and of the "new philosophy," experimental learning. Dr. Wilkins' moderate and tolerant rule of the college during the years of the Commonwealth made it attractive to the sons of cavaliers and roundheads alike, and drew about him in or near the college such science-lovers beside Wren as Robert Boyle, Laurence Rooke, Dr. John Wallis, William Petty and Seth Ward. These men with others of like interests formed the philosophical or scientific club that met first at Dr. William Petty's lodgings and then at the Warden's rooms with greater or less regularity until Wilkins resigned in 1659 to become Master of Trinity College, Cambridge. With these men at Oxford, most of whom were later to be charter members of the Royal Society, Wren found most congenial and stimulating companionship, and they a genius whom Evelyn called "that miracle of a youth."[9] Evelyn wrote in his diary 13 July, 1654, that he had dined at the college with Warden Wilkins and that the Warden had "above in his lodgings and gallery, variety of shadows, dials, perspectives and many other artificial, mathematical and magical curiosities, a way-wiser, a thermometer, a monstrous magnet, conic and other sections, a balance on a demicircle; most of them his own and that prodigious young scholar, Mr. Christopher Wren; who presented me with a piece of white marble which he had stained with a very lively red, very deep, as beautiful as if it had been natural."

Wren's fertile brain was too active during these ten or twelve years to be limited to any one field. In the "Parentalia" is a list of fifty-three "New Theories, Inventions, Experiments and Mechanich Improvements, exhibited by Mr. Wren, at the first Assemblies at Wadham-College in Oxford, for Advancement of Natural and Experimental Knowledge, called then the New Philosophy; some of which, on the return of the publick tranquility, were improved and perfected, and with other useful Discoveries, communicated to the Royal Society."[10] They range from a "picture of the Pleiades," and an "artificial eye with the humours truly and dioptically made" to "several new ways of graving and etching," "divers new musical instruments," and "the best ways for reckoning time, way, longitude and observing at sea." The practical applications of his experimental knowledge were a constant con-

[6] *Ibid.*, p. 184.

[7] *Loc. cit.*

[8] Robert B. Gardiner, "The Registers of Wadham College, Oxford, from 1613 to 1719," p. 178. London, 1889.

[9] "Diary," July 11, 1654.

[10] "Parentalia," pp. 198–199.

cern to him, this problem of the determination of longitude, for instance, recurred to him again and again throughout his life, and even occupied his old age after his retirement from public office. It was during this Oxford period too that he solved the mathematical problem sent by Pascal by way of challenge to the mathematicians of England. In return Wren posed another problem to which the French savants never replied.

The virtuosi at Oxford must have rejoiced at the recognition given Wren in 1657 when he was appointed professor of astronomy at Gresham College in London though he was not yet twenty-five years old. The opening paragraphs of his inaugural speech were as follows:

> Looking with respectful awe on this great and eminent auditory, while here, I spy some of the politer genii of our age; here, some of our patricians; there many choicely learned in the mathematical sciences, and everywhere, those that are more judges than auditors; I can not, but with juvenile blushes, betray that which I must apologize for. And indeed I must seriously fear, lest I should appear immaturely covetous of reputation, in daring to ascend the chair of astronomy, and to usurp that big word of demonstration, *Dico;* with which (while the humble orator insinuates only) the imperious mathematician commands assent; when it would better have suited the bashfulness of my years, to have worn out more *lustra* in a Pythagorean silence.
>
> I must confess I had never design'd anything further, than to exercise my radius in private dust, unless those had inveigh'd against my sloth and remissness, with continual but friendly exhortations, whom I may account the great ornaments of learning and our nation, whom to obey is with me sacred, and who, with the suffrages of the worthy senators of this honorable City, had thrust me into the publick sand. That according to my slender abilities, I might explain what hath been deliver'd to us by ancients, concerning the motions and appearances of the celestial bodies, and likewise what hath been found out of new by the modern; for we have no barren age; and now in this place, I could point to inventors; inventors, a title so venerable of old, that it was merit enough to confer on men patents of divinity, and perptual adoration.[11]

[11] *Ibid.*, p. 200.

Gresham College of the seventeenth century is to-day little known as compared with Oxford and Cambridge; but to the citizens of London in the century of the Stuart kings, it was an important center of learning. Founded by the will of Sir Thomas Gresham, Queen Elizabeth's financial adviser, it began its career in 1597 in what had been his residence. There the seven professors of geometry, astronomy, music, rhetoric, medicine, theology and jurisprudence lectured and had their living quarters, and there the virtuosi of the day, many of them newly returned to London, came on Wednesdays to hear Mr. Wren lecture on astronomy and on Thursdays to attend the geometry lecture of Mr. Rooke. One of Wren's lectures was on the telescope, to the improvement of which he had greatly contributed. Another was on the planet Saturn, then a topic of especial interest. As part of his work he invented a method for the construction and demonstration of solar eclipses. After the lectures his friends would gather in the lecturer's apartment to discuss with him and with the other virtuosi not only the topic of the afternoon but other subjects of common interest. Finally out of these discussions, the roots of which ran back to the weekly meetings of the Oxford science-lovers, and of the "invisible college" group in London of the forties and fifties, developed the idea of a formally organized society to be under royal patronage for the furtherance of natural knowledge. On November 30, 1660, at the meeting after Mr. Wren's lecture this decision was crystallized, the society founded, and in 1662 it was chartered as the Royal Society.

In this first charter of 1662 are listed the officers and the members of its first council while those who formed the membership that year were the original or charter fellows. On the first council was named Mr. Christopher Wren, "doctor

in medicine."[12] This reference to Wren as "doctor in medicine" is interesting; for I have found no other reference or evidence showing that Wren ever received the M.D. Oxford gave him the D.C.L. in 1661 and Cambridge later the same honor, but not the medical degree. On the other hand, by 1661 Wren had already done so much work in anatomy and dissection not only as an assistant to Dr. Scarborough before he went to Oxford, but with Dr. Willis and the other physicians at Oxford that perhaps the fame of his anatomical drawings made whoever wrote the list of names identify him as "doctor in medicine" along with the medical men also on the council. Whatever the reason for this title, Wren's name was only in the first council list and not in the second of 1663, probably because having resigned his Gresham professorship in 1661 he had returned to Oxford after his appointment there as Savilian professor of astronomy.

Whether in London or in Oxford, he was a moving spirit of the Royal Society in its early days, often reporting before it on his own experiments and suggesting ways, particularly in the recording of weather conditions, how the fellows could all further most important but hitherto neglected parts of natural knowledge. When the Society in 1661 [*sic*] was preparing to receive King Charles II as a guest at one of its weekly meetings, Wren proposed from Oxford various demonstrations for his entertainment in answer to a letter from the president, Lord Brouncker, asking for suggestions. Wren's reply[13] is worth quoting in part, for in discussing what he considered proper for such a solemn occasion he reveals his own interests, and also his good practical sense; for, he commented, what is shown should at best "open new light into principles of philosophy," and in any case should be "something luciferous in philosophy and yet whose use and advantage is obvious, and without a lecture; and besides may surprize with some unexpected effect, and be commendable for the ingenuity of the contrivance." He continued:

> For myself I have not anything by me suitable to the idea I have of what ought to be perform'd before such an assembly. Geometrical problems, and new lines, new bodies, new methods, how useful soever, will be but tasteless in a transient show. New theories, or observations, or astronomical instruments, either for observation or facilitation of the calculus, are valuable to such artists only who have particularly experimented the defects that these things pretend to supply. Sciographical knacks, of which yet a hundred varieties may be given, are so easy in the invention, that now they are cheap. Scenographical, catoptrical and dioptrical tricks, require excellent painting, as well as geometrical truth in the profile, or else they deceive not. Designs of engines for ease of labour, or promoting anything in agriculture, or the trades, I have occasionally thought upon divers, but they are not intelligible without letters and references, and often, not without something of demonstration. Designs in architecture, etc., the few chymical experiments I have been acquainted with, will, I fear, be too tedious for an entertainment. Experiments in anatomy, though of the most value for their use, are sordid and noisom to any but those whose desire of knowledge, makes them digest it. Experiments for the establishment of natural philosophy are seldom pompous; 'tis upon billiards, and tennis balls; upon the purling of sticks and tops; upon a viol of water, or a wedge of glass, that the great Des Cartes hath built the most refined and accurate theories that human wit ever reach'd to; and certainly nature in the best of her works is apparent enough in obvious things, were they but curiously observ'd; and the key that opens treasures, is often plain and rusty, but unless it be gilt, 'twill make no show at court. If I have been conversant in philosophical things (as I know how idle I have been) it hath been principally in these ways. . . .

He finally suggests from among his own devices, "the weather-wheel (the only true way to measure expansions of the air)," an artificial eye—"at least as big as a tennis ball," and lastly "a needle that would play in a coach" (a kind of compass) and joined with a way-wiser

[12] "The Record of the Royal Society of London," 4th edition, p. 229. London, 1940.
[13] "Parentalia," pp. 224–227.

(an odometer) would be both useful and diverting to a traveler and also might be an acceptable present for the king.

From this list the reader can see that Wren's love of experimental learning was not limited to the mathematical and physical sciences—astronomy, optics and mechanics—but extended to the chemical and anatomical ones as well. It is also apparent that practical applications were of primary significance to him. His inventive ingenuity was constantly at work whether to devise an instrument of two pens for writing double, to construct a weather gauge to measure rainfall or an instrument to record temperature changes throughout the twenty-four hours, or to regulate the size of aperture for telescopes and microscopes. His mechanical genius was so marked that his fellow worker Robert Hooke, an inventive genius himself, wrote of Wren in 1665: "of him I must affirm that since the time of Archimedes, there scarce ever met in one man in so great a perfection such a mechanical hand and so philosophical a mind."[14]

Like his love for mathematics, Wren's skill of hand and inventive ability were apparent very early in his life. As a lad in his teens he had not only acted as a demonstrator for Dr. Scarborough in his public lectures at the Surgeon's Hall but he had made anatomical models for him out of pasteboard. This anatomical work, especially on the muscles of the human body, was believed the first in anatomy to be based on geometrical and mechanical principles.[15] Unfortunately these models were destroyed in the Great Fire some twenty years later. At Oxford in his student days Wren continued his anatomical studies, working with Dr. Willis on his classic dissections of the brain and drawing the plates of these dissections for Willis's book "Cerebri Anatome" (1654). In fact Dr. John Fulton pointed out some years ago that "Willis mentions that Wren made the remarkable figure of the base of the brain which shows so clearly the arterial circle." Dr. Fulton continued: "I have always suspected that it was Wren and not Willis who made the discovery of the circle, for the vessels that he drew had evidently been injected and the plate itself is very much clearer than Willis's description in the text."[16]

The structure of fishes, the anatomy of nerves, the character of various organs in animals, and the humors of the eye with attendant problems of wisdom—all these attracted Wren's attention and provided problems he sought to solve. To the twenty-four year old Wren are credited the first suggestion and successful demonstration of the infusion of a liquid directly into an animal's vein—a procedure startling in its novelty in 1657, and one that had as its immediate successor in 1659 the transfusion of blood from one animal to another and later from a sheep to a man.[17] Experiments in transfusion, indeed, became quite the fashion in experimental circles during the early 1660's as Wren's ideas and methods were developed by other virtuosi. For some of this scientific work Wren used the crude microscopes of the period; immediately he found ways to improve both the lenses and the use of them as well as to record what they revealed. His drawings of a louse, a flea and a nit as seen under a microscope found their way into the cabinet of treasures owned by King Charles and led to a request from the king that he do more of these "divine works" (to use Sprat's name for them).[18] By this time, however, Wren was deep in other matters and he asked the king for release from this task. He encouraged Robert Hooke to go on with these studies instead, with the result that in 1665

[14] "Micrographia," Preface. London, 1665.
[15] "Parentalia," p. 187.
[16] Fulton, *op. cit.*, pp. 313–314.
[17] "Parentalia," pp. 227–235.
[18] *Ibid.*, p. 258.

Hooke published his "Micrographia," the classic book on microscopic work.

This attitude toward his work was apparently characteristic of Wren. He had far more ideas and schemes than he could carry out himself, he cared not for fame nor for credit, and only occasionally did he bother to record priority of discovery when he found others disregarding his accomplishments or claiming his ideas as their own. As his biographer wrote:

> His communicative temper in lending out papers, never recovered; his peculiar modesty and disregard of publick applause, and of those methods by which men of the world usually proclaim and support the merits of their own performances, prevented the appearance in public, under his own name, of many useful tracts, and occasioned his not carrying on divers discoveries to perfection.[19]

Some of Wren's friends in their loyal admiration were jealous of his fame for him and did their best to have justice done him. When Thomas Sprat wrote his "History of the Royal Society" in the years before 1667, he described Wren's activities in some detail as a most notable illustration of the work being done by the fellows. Sprat did this because he found the Society's records were incomplete, "many excellent things, whose first invention ought to to ascribed to him," having been "casually omitted."[20] On this point the biographer remarked:

> Sir Christopher has been heard sometimes to reflect sharply on the disingenuity of Mr. Oldenburg [one of the two secretaries of the Royal Society] who had neglected not only to enter divers inventions and experiments of his in the Registers of the Society, but conveyed the same into foreign parts, France and Germany; where they were after published under other names, as their own.[21]

Wren was not yet thirty when he returned to Oxford, in 1661, to be Savilian professor of astronomy, and all his architectural achievements were still ahead of him. Yet the next year Isaac Barrow, whom Charles II called the best scholar in England,[22] in a lecture at Gresham College spoke of Wren as follows:

> There is definite agreement that no one ever displayed more precocious hopes, so no one has produced riper fruits; formerly a prodigy of a boy, now a miracle of a man, or rather a supernatural (daemonic) human being; and moreover so that I may not seem to be a liar, it should be sufficient for me to have named the most gifted and superlatively good Christopher Wren.[23]

It is not to be wondered at that Wren was welcome company among the best minds of the time. He it was who suggested to Robert Boyle to use mercury in his barometer tube, who had John Evelyn as godfather for his first born son, and who was consulted by Seth Ward, when Bishop of Salisbury, about the repair of that beautiful cathedral. Sprat's letters to his "Kit Wren" are full of friendship and good humored admiration. And Charles II called Wren up to London in 1663 to consult about the repairs that were most necessary for that sadly dilapidated church, St. Paul's. Wren even then advocated a cupola for that building in place of the much loved but very unsafe steeple; but he did so unavailingly for tradition and public opinion were against him, until the destruction wrought by the Fire of 1666 made necessary the complete demolition of the old structure. The king put Wren in charge of the rebuilding of the City after the fire; and when the old surveyor-general of the royal works finally died in 1669, he at once commissioned Wren as his successor. With the development of his responsibilities as an architect, Wren had to withdraw from his more specialized scientific pursuits. He resigned his Oxford professorship in 1673, when he

19 *Ibid.*, p. 247.

20 Thomas Sprat, "History of the Royal Society," pp. 311–317. Second edition. London, 1702.

21 "Parentalia," p. 247.

22 Walter Pope, "Life of . . . Seth, Lord Bishop of Salisbury," p. 164. London, 1697.

23 Ward, *op. cit.*, p. 97.

was forty, but he found time to serve as president of the Royal Society in 1680–1682. Always, he had the furtherance of science at heart, even seeking to plan the Monument, and also the great staircase in St. Paul's to serve as tubes "to discover the parallax of the earth" as an aid to astronomers.

Mathematician, astronomer and physicist, meteorologist, anatomist and chemist, inventor and architect, skilled draftsman and excellent Latinist, honest craftsman and public servant—Wren was in the opinion of Pepys, "a worthy man."[24] Before Wren was thirty-four years old, the Fire of 1666 practically put a close to his scientific career, even though he was later to be president of the Royal Society. After 1666 Wren became preeminently the architect, probably the greater in his new field because of his remarkable skill in mathematics, especially in geometry, and his exceptional powers of draftsmanship as was manifest in connection with his anatomical and microscopic studies. Essentially modern in his application of theory to practical use, he would surely with his "way-wiser" and his double-writing instrument, for example, have also felt at home among the inventors of gadgets to-day. But these were the trifles, dreamed of, tried and passed on for other men to develop or not as they would.

[24] "Diary," March 21, 1668–69.

If you seek his true monument, go to St. Paul's and look around you. As architect, as scientist and as a versatile genius, Wren's work gives considerable foundation for Warden Herbert A. L. Fisher's comment on him, "possibly the greatest Englishman after Shakespeare."

YOUTH AND EDUCATION

CERTAIN broad over-all changes occurred in the lives and expectations of young people as a class during the decade 1930–1940. Census data tell us that the proportion of boys and girls aged fifteen to nineteen, inclusive, who were in school and not working increased by 25 per cent. This took place in a nation which already was schooling more of its older youth than any other country in the world. The proportion of young people who were employed decreased during that same period by more than 30 per cent. The number of boys not in school and not working increased in the first half of the decade and then decreased toward its close. . . .

What happened in the schools and colleges during the 1930's? How did they respond to the social and economic changes of the period? They responded slowly, for educational institutions are conservative. Boys and girls in the average school or college in 1940 took more or less the same courses that their predecessors took in 1930 and in 1920. But in a number of schools and colleges, a ferment has been at work, and trends are now apparent that may make great differences in the high schools and colleges of 1950 or 1960. In at least a hundred secondary schools and about fifty colleges that education of 1940 is notably different from that of 1930. Central High School of Tulsa, Oklahoma, is one case where considerable changes have taken place. . . .

In 1930, as in 1920, the high-school courses of most of the students in Tulsa were dictated by college entrance requirements, although not more than 15 or 20 per cent. were to sit in a college classroom. In 1932 the Tulsa Central High School began to take part in the Eight Year Study of the Progressive Education Association involving thirty secondary schools, and thus was freed from meeting the ordinary college entrance requirements for certain specified courses. . . .

Young people in Tulsa assumed more responsibility for planning their own education. To manage their classes, they formed committees to work with the teachers, and had individual talks with them leading to better mutual understanding as time went on. Part of the day each student worked on projects which he chose as his way of making a contribution to some common problem. The study of such community problems as health and housing was begun and, with their English teachers, they related their work in reading and writing to their work in civics and science.—*Annual Report of the General Education Board, 1940.*

THOUGHTS ON SUBSPECIES

By W. L. McATEE

FISH AND WILDLIFE SERVICE, U. S. DEPARTMENT OF THE INTERIOR

RECOGNITION of avian subspecies has been the subject of comment more often aspersive and rancorous than judicial and broad-minded. The rank and file of American ornithologists and often, also, the leaders have dealt with subspecies as hard facts, to the neglect of underlying principles. Not a systematic ornithologist, the writer worked for twenty years on the classification of insects and described hundreds of species (as well as many subspecies and varieties) of those animals. This should be sufficient background for a discussion of subspecies, and experience with a group other than birds should give a detached point of view not easily attained, perhaps, by those who have been in the thick of the ornithological subspecies battle.

The writer has also been more or less deeply absorbed in bird study since boyhood and he has never worried about a subspecies yet. Why worry? There is no compulsion to deal with subspecies upon those who do not wish to do so. Oologists, especially, have denounced hair-splitting and name-changing, but why did not those who felt that way simply ignore subspecies? By taking them too seriously, they permitted others to rule their specialty. They need not have striven for a "set" of every additional form named; they could have made their own catalogue of what they deemed "good species" and have used it as standard in their guild.

Observers who study ornithology for pleasure (the vast majority) need not take account of subspecies—which are rarely subjects for field recognition anyway. These students legitimately may be, and mostly are, interested in birds primarily, in species, secondarily, and in subspecies, not at all. If necessity arises, they can read in some book what is known about the subspecies concerned.

The need for bird names on the part of ornithologists, who care not for subspecies, can be met entirely by a code of vernacular names of species (not provided, it must be admitted, by the current A.O.U. Check-List). These bird students, if they will, can go their way in peace wholly untroubled by the doings of the subspecies makers and check-list compilers.

What of those who do care for subspecies and want to use subspecific names? Considering the advantage they should have in commenting upon subspecies, some of their remarks have been about as pointless as those of ornithologists far less informed. For example, we read that "subspecies may be sharply defined or they may also be united by intermediates." This pronouncement ignores the very definition of subspecies; they are forms connected by intermediates; the "sharply defined" forms are species. Some have railed at subspecies because every collected specimen can not be promptly and positively identified. If the going were as easy as that, it would indicate that species, not subspecies, were being dealt with. Subspecies are not another kind of thing like species, but less well marked—no, they are fractions of species—colonies, the individuals of which are in no way trenchantly marked off from those of other colonies.

Often we read of "good" or of "poor" subspecies, terms that are not properly applied to segregates correlated with geography, physiography and ecology, and just as valid as the distinctions in their habitats whatever the degree of

expression. In a word, many, perhaps all, species tend to be modified in response to environment. A species between the extremes of its distribution may range over a number of types of country in each of which it may develop precinctive characteristics. These diversities are correlated with environment. Whether caused by environment, and how, are separate questions. As changes in environment are usually gradual, so those in color, form and measurements of the bird inhabitants, as a rule, are intergrading in character. Species embrace individuals that are most closely like their nearest neighbors, and those neighbors with the next beyond and so on. Such intergradation is known to extend clear across the continent and connect forms, which if the intermediates were eliminated would rank as distinct. The greatest American ornithologist has compared such a complex of subspecies to the imperceptibly merging colors of the spectrum.

Sometimes, however, birds having the subspecific characters of one region are found breeding in another area. These may be strays or mutants or they may represent other aberrations of distribution or heredity. Such mixtures of genetic strains may in certain instances obscure the subspecies concept, but they do not affect its general validity.

Some birds are more plastic, reflect environmental change more than others, but theoretically any species of wide range, if it have the attachment to territory now held to be characteristic of practically all birds, theoretically at least, it may be repeated, such a species must be affected in some degree by any differentiation areas included in its general range.

The reality of differentiation areas may be brought home by consideration of the results of subspecific classification as officially accepted by the American Ornithologists' Union (1931 Check-list). Florida, for example, has more than thirty subspecies nearly or entirely restricted within the limits of the state, so far as distribution in the United States is concerned. Individuals of a number of these races average smaller than those of the next adjacent subspecific segregate. For another southern illustration, consider the tip of Lower California or the Cape District, from which nearly fifty currently recognized subspecies have been described. Here is a district limited in size and in ecological variety but one which is an avian differentiation area with emphasis. The northern part of the peninsula also has yielded about an equal number of recognized subspecies. Probably all have read about the Brownsville birds and the furor they caused. They were sixteen in number; now about fifty subspecies are known to occur in the United States only in southern Texas. An equal array range from the next adjacent district of the arid Southwest through similar country in Mexico and a goodly number are found only in the mountains farther west and in comparable parts of the Mexican Tableland. The desert forms are notable for their pallor, while those of the humid northwest coast are characterized by somber coloration. There are about forty subspecies in the latter group, mostly ranging from southern Alaska or British Columbia to Oregon or northern California. The northeast coast also is a differentiation area, twelve subspecies now being recognized from the Newfoundland, Nova Scotia, New Brunswick region.

It is easiest to deal with peripheral parts of our territory, but it should not be overlooked that the mid-continent also has peculiarities that are reflected in differences in the bird inhabitants. For instance, the zone of transition from the humid east to the arid west south of the transcontinental coniferous forest is one of vast significance in the distribution

and modification of organisms in general. Among birds, we recognize an eastern and a western willet, solitary sandpiper, dowitcher, mourning dove, yellow-billed cuckoo, house wren, mockingbird, robin, golden-crowned kinglet, ruby-crowned kinglet, warbling vireo, yellow-breasted chat, meadowlark, evening grosbeak and eastern and western subspecies of the Savannah, Henslow's, vesper, lark, tree, chipping and field sparrows.

Geographic, physiographic, ecologic, or whatever the influence forming subspecies may be, obviously it is of great importance in connection with the differentiation of birds and when coupled with isolation, its effects often are intensified. The island forms well illustrate this point: more than twenty accepted subspecies have been described from the California and Queen Charlotte Islands, four from the latter group alone. Seven subspecies of rock ptarmigans and six of winter wrens are recognized from islands of the Aleutian chain. The clapper rails, marsh wrens and seaside sparrows from almost every sizable tract of salt marsh seem to be distinguishable and numerous subspecies have been described.

No more need be said to prove the existence and the effects of differentiation areas. They would no doubt appear more definite had progress in bird classification been less haphazard. Forms were described as they came to hand and ranges worked out later. Often the type specimen was a variant that would not have been selected had more material and fuller knowledge of ranges been available. Then another describer may have defined a form distinguishable from those previously described, but still for lack of material and knowledge, not centrally located in its area of differentiation.

How much better could all this have been done if the concept of differentiation areas could have been developed first, and a grid of those areas prepared that would show where recognizable variants of any wide-ranging and plastic species might be expected. It would seem self-evident for every such species, considering its continuously intergrading variation, correlated with environment, that there will be in each differentiation area an association of individuals more like each other than like those of other areas, that may be recognized as subspecies if desired. If our beliefs as to territorialism and environmental response are correct, local populations will in some degree be modified in the differentiation areas whether the effects are readily discernible or not. In other words, named or unnamed, subspecies of some degree are present in each differentiation area. This is a phenomenon of nature, not a fancy of man. Practice as to description of these forms is in the hands of the taxonomists, and policy as to official acceptance of them in those of the Committee on Classification and Nomenclature. As to use of the names, no one need use them; that is a matter of choice.

The facts are plain, however, and recognition of them should put an end to carping of big-wigs about millimeter races, and complaining by little-wigs as to the prospect of every county having a separate subspecies of each bird. Furthermore, the supposedly devastating criticism that a bird without locality label can not be identified to subspecies is no criticism at all, for it is precisely localization and local environmental moulding that permit subspecies to be defined. A safe rule would be not to attempt subspecific identification except of known breeding birds very precisely labeled as to locality.

On this point Taverner writes, "It is very important that subspecies be made only from breeding birds. The naming of migrants or winter-visitors and then

guessing as to their probable origin is responsible for much misleading work. . . . If no one ever made a subspecific identification without observed subspecific evidence ornithology would be a long way ahead today'' (letter of April 21, 1938).

If continuous intergradation through the range of continental species is the universal phenomenon it appears to be, then all specimens can not be sorted to subspecies except on a geographical basis. In a great deal of subspecific definition that has been done, the lines of separation between the forms, which it has seemed advisable (to the author, compiler or committee) to name, have been arbitrary. The accepted limits of life zones or of other ecologically significant areas, consciously or unconsciously, however, have been the guide in numerous instances. If a subspecific grid such as suggested here could be worked out as representing generally effective differentiation areas, the problem of what to recognize would be much simplified. It would be of great value also in enlightening critics as to the inevitability of subspecies and as to the realities underlying subspecific nomenclature.

SCIENCE AND MORALS

By JOSEPH B. GITTLER

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VERY few people will disclaim the fact that there is an enormous amount of confusion in the ethical thinking of the present day. Much disagreement eddies about the problems of the criteria of good and bad. A group of college seniors were questioned about the rightness of lying and killing. Without hesitation their reply was that both were wrong. When asked further whether lying was right in the case of a physician telling a heart patient that he had two months to live, thus subtly killing him much sooner, the answer became more hesitant. It was generally considered that to lie is bad, but to kill is much worse. When questioned again as to the badness of lying, the students became more confused and were in a quandary.

I cite this as one illustration of the confusion that exists in our everyday ethical thinking—it is not difficult to see why this chaos prevails. The confusion is due largely to the arbitrary, conventional and traditional manner that we have adopted in determining our criteria of good. This arbitrary selection of standards has taken many forms. The standards of good are often set up and accepted by the individual or group, without any intellectual questioning of the standard; or without ever having had the occasion to witness or to experience that good. We can illustrate the former by the fact that a great many people are proud of being ''modern.'' The latter may be illustrated by a group of twenty-five students, twenty of whom considered that it would be worth while to reintroduce the practice of the minnesingers; of these twenty, only two were familiar with the age of the minnesingers. The others knew only that they were those who used to compose popular medieval lyrics. Five of the total did not commit themselves.

Confusion arises too in our ethical thinking when people hesitate to question existing institutions. All the twenty-five students considered it worth while to go to college, because 'every one goes to college these days.'

M. R. Cohen's illustration by a parable in his ''Reason and Nature'' shows this

dilemma clearly: "Suppose that some magician came to us and offered us a magic carriage having great conveniences, but demanded of us in return the sacrifice of thirty thousand lives every year. Most of us would be morally horrified by such an offer. Yet when the automobile is actually with us, we can invent many ingenious arguments against the proposal to abolish it."

Although the above difficulties are characteristic of the so-called "common-sense" group, the confusion becomes even greater when moral philosophers furnish us with subtle substitutions for arbitrary standards of good. I refer to the metaphysical-ethical theories of teleology, formalism, hedonism, and so on.

For the purpose of this paper I wish to classify ethical thinking into two general schools: the absolutist and the relativist.

The confusion surrounding the absolutist way of thinking may again be illustrated by the situation about lying cited previously. Let us consider the commandment "Thou shalt not kill." If we were to apply this commandment absolutely the absolutist would of necessity have to be a vegetarian, for to kill an animal is as wrong as to kill a man. Further, an absolutist tending to uphold heroism can hardly, also, account for laurels won for brave deeds, which must of necessity consist of prizes for bigger and better killing.

On the other hand, the relativist who fails or hesitates to accept the existence, validity, reality, of moral standards can easily be led to a moral morass which might be even more chaotic than his absolutist brother.

It is therefore the contention of this paper that in order to overcome this confused state of affairs, we must employ a scientific approach to our ethics and morals. I am fully aware of the objections raised to the employment of science in ethics—objections ranging from the lack of desire to employ it to the claim that ethical man is not a scientific creature.

It is not so much the intention of this paper to answer the persistent objections raised against a science of ethics. Rather it is my intention to point out ways in which we might make some progress in our ethical thinking. To my mind the solution lies in the adoption by ethics of that phase of the scientific method which is applicable here, *viz.*, the universal-rational and the objective.

I do not propose to go into an elucidation of the scientific method as such; neither do I claim that the general accepted procedure of science is totally applicable to the moral realm—but I see in some phases of science a possible approach to a better understanding of our morals and of our ethical evaluations.

Our mode of procedure might be as follows. Instead of hapahazardly and arbitrarily considering anything as good, rather let us consider what are the inevitable and necessary facts of human nature, such as desire for food, life, sex, health, and so on. In short there are certain things that must be, before other things should be. Anything that tends to destroy life or civilization, such as war, poor hygienic conditions, disease, etc., have to be considered as bad; things that tend to satisfy man's fundamental wants, as good. There are, however, some modifications. Thus we may start with the fundamental assumption that personal possessions are essential and necessary. We may then employ this law in society. It will then lead us to a qualification of this principle, *viz.*, if in society all people seek personal possessions, these possessions must become limited in so far as the interests of the many are concerned. Thus we are also overcoming the possibility that the overemphasis of one need, as sex, may become detrimental to another need as life itself.

It is this phase of science that is both helpful and remedial to our confused state of morals. Before we can proceed to declare what good should prevail, we must discover what human activities must prevail. This is synonymous with the discovery of natural laws. It will not be difficult to ascertain these inevitable goods. The manner in which this can be done, while sometimes considered dialectical is, however, not accurately described by that term. I refrain from culling a name for this type of procedure, but wish to point out just what it is. (I might here mention that this very inadequacy and inexactitude of language has led to the creation of semantics and symbolic logic.) Let me use an illustration to clarify my point. The N.R.A., the institution of Ford, are not inevitable to man— remove these institutions and man can still exist in various other ways—however, take away food or means of getting food and man is eliminated altogether. The latter illustrates inevitable values. This has the earmarks of the biological approach in ethics, but that is merely because of the example used. Beauty may be fundamentally essential to man as well. Beauty may prove destructive to man—it must be tested by inevitable values.

Even though this procedure does not eliminate the probable character of ethical judgments, we must be ready to accept the method of caution rather than one of whim and sentiment. To the complaint that the enumeration of the fundamental facts may become more complex and more involved and the consequent criteria of good more pluralistic, our answer is that the law of gravitation does not apply to colloidal chemistry. If we make it apply—and perhaps by some schematic instrument of logic we can make it apply—it would not be significant as a law of natural phenomenon at all. Moral phenomena are more numerous than types of natural phenomena and there consequently must be expected a larger number of hypotheses or generalizations.

Ethics is interested in creating a good man and a good society. The advantage of the moral over the natural is that the natural phenomena are and must be as we discover them; moral phenomena have to do with intelligent activity which should be used as an instrument of accepting if good, and rejecting if bad.

A great many thinkers consider this method autocratic. We surely ought not to be sidetracked by such irrelevancy; for in so doing they are merely making an appeal to our emotions and raising objections which cloud the issue. If a thing is good, having been arrived at in the method described above, then we ought conscientiously to pursue that thing. We ought not to quibble about autocracy—we ought to be delighted to follow what is right.

THE MYTH OF POISON GAS

By MORRIS GORAN
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SEVENTY-EIGHT thousand soldiers died from the effects of poison gas in the World War; one million more were counted as casualties from this weapon. On the other hand, approximately eight and one half million men were killed, and twenty-one million men were wounded through other means. Thus the poison gas toll is less than one per cent. of the total, with the great majority of casualties occurring during the early years of the war, when gas masks had not been developed.

These facts have not impeded a constant attack against poison gas; people shocked by modern warfare point to it as a symbol of the horror. But whether or not worthy of the reputation, every new war weapon has been similarly received. When fire-arms were first used during the Middle Ages, there was a like vilification against the introduction of barbarian practices.

According to the most recent treatise on chemical warfare (by Lieutenant Colonel A. M. Prentiss, of the United States Chemical Warfare Service), the French were actually the first to use poison gas. Ethylbromacetate, a lachrimator or tear gas was used in French rifle grenades as early as August, 1914. Due to the shortage of bromine, a chlorine compound was substituted in November, 1914. The chloracetone used was a toxic lung injurant.

Whatever amount of tear gas was used in the French rifle grenades and German artillery shell, real gas warfare began with the German gas-cloud attack at Ypres, Belgium, on April 22, 1915. Nearly six thousand large and small cylinders containing chlorine were installed by the Germans in their front-line trenches. After this attack, the poison gas weapon was adopted by the Allies and by every army division on both sides.

The credit for the German gas attacks has been given to Fritz Haber, chemist, patriot, soldier and statesman, who died in exile from the ungrateful Nazi government. Although having engineered the first and other successful gas attacks, he may have been merely the scapegoat to receive abuse in the event of world-wide protest. The real instigator may have been Professor Walter Nernst, professor of chemistry at the University of Berlin. Shortly after the use of gas had been started, Nernst was decorated by the Kaiser for his "notable services," while Fritz Haber gained only the title of captain in the army and abuse in scientific circles outside Germany.

Such a possible intrigue is not new in history nor in the history of poison gas. During the Crimean War in 1855, the English Admiral Lord Dundonald, having years before noted the suffocating character of the fumes near the sulfur mines in Sicily, proposed to conquer Sebastopol through the use of sulfur fumes. The English government disapproved the measure. But the prime minister, Lord Palmerston, discussing the matter in a personal letter to Lord Panmure, wrote: "If it succeeds, it will, as you say, save a great number of English and French lives; if it fails *in his hands,* we shall be exempt from blame, and if we come in for a small share of the ridicule, we can bear it, and the greater part will fall on him."

The idea of poison gas warfare, however, did not originate with the English during the last century. In the war

between the Spartans and Athenians (431–404 B.C.), the Spartans saturated wood with pitch and sulfur, and burned it under the walls of cities, asphyxiating gases being liberated. More famous is "Greek fire." Its composition as far as ascertained (for its secret has been lost) shows not only readily inflammable substances as pitch, resin and petroleum but also sand and quicklime. If such were the constituents, the quicklime by being quenched in water generated enough heat to ignite the petroleum, which in burning developed sufficient heat to ignite other combustibles. The light hydrocarbons evaporating from the petroleum formed an explosive mixture with air, and in exploding developed enormous quantities of smoke and soot. Also sulfur caught fire, and in its combustion formed the asphyxiating gas, sulfur dioxide. The invention of "Greek fire" is believed to have occurred at about 600 A.D., and there is evidence of its use during the Crusades.

Twenty-six nations at the first Hague Peace Conference in 1899 pledged themselves not to use projectiles giving out suffocating or poisonous gases in warfare. Captain Mahan, the United States delegate, refused to sign, arguing that such pledges were meaningless when heavy arms and explosives were used without scruple. At the second Hague Peace Conference, in 1907, the United States delegate still refused to sign the document.

Although Germany violated this agreement with a large-scale attack, the use of poison gas by Germany should not have surprised the Allies. A deserter at Ypres, captured by the French, warned the French Divisional Commander of the impending attack, showed a primitive gas mask in support of his claims. General Ferry, believing the story, warned officers in the neighboring sectors and his superior officers. The latter ridiculed Ferry for believing the story and laughed at his suggestions that the German trenches be shelled in order to destroy the cylinders, and that the number of men in the front-line trenches exposed to the danger be reduced.

Besides the deserter's story the Allies had sufficient basis on which to expect a gas attack. Trench warfare and the power of modern impact weapons had brought a deadlock on the Western front. Gas had to be used in order to restore movement in battle, permit tactical maneuvers and open the way to victory for one side or the other. And gas was the weapon most available to Germany. Preceding the war, its chemical industry had been developing to an amazing extent. In 1913, there were nearly fifteen thousand chemical factories in Germany, many of which were in the dye industry. In 1913, Germany produced three fourths of the total world output of dyes and at the same time more than 85 per cent. of the dye-intermediates. A few simple chemical operations changed many dyes and dye-intermediates into poison gas chemicals. Hence the military importance of the dye industry. Also its mobilization for war purposes in Germany was simplified by the corporate structure. The major portion of the industry was controlled by a holding company, the *Interessen Gemeinschaft Farbenindustrie*, and manufacturing activities were directed from a central office in Berlin.

With such tremendous resources for poison gas, Germany lost the war. The possibility of victory through its use was lost when Germany failed to produce greater and more frequent gas attacks when the Allies were unprepared, when defense measures were negligible. After the introduction of masks, gas became a very weak weapon.

Only very few chemicals are suitable for use in poison gas warfare. In the World War, over three thousand chemical compounds were selected and investigated from the approximately four hundred thousand known. About thirty met

requirements for actual use and only six were extensively employed by Allied and Central Powers.

To-day the list is probably not larger, because a chemical to be used in gas warfare must meet other requirements besides being poisonous. It must be cheap, easy to manufacture, chemically stable and capable of vaporization. Very few compounds vaporize under ordinary conditions, or conditions on the battlefield. All the light molecules which vaporize are already known, and there is ample protection against the poisonous ones. Whatever the possibility (known to be very small) for the discovery of heavier, vaporizing molecules to be used as poison gas, protection is at hand. Charcoal can absorb such regardless of the composition.

As a poison, a gas is usually classified as either one of five: Lachrimator or tear gas, sternutator or sneeze-producer, lung injurant, vesicant or blister-producer, and nerve poison. When it is capable of being in many classes, the chemical gains favor for use. Both multiple effectiveness (in more than one class) and toxicity is found in phosgene, which accounted for 80 per cent. of the gas fatalities in the World War. Mustard gas, also deadly and multiply effective, was used during the last stages of the war. It was discovered after gas masks had been introduced, when German chemists sought either a lung injurant which would penetrate the mask or an entirely new type of gas which would attack other parts of the body. The result was mustard gas and diphenylchlorarsine. These were mainly vesicants as are more recent discoveries: Lewisite, methyldichlorarsine and dibromethyl sulfide. Protection for the entire body must be had to guard against vesicants, and every modern army has such protection.

The same can not be said for civilians. Outfitted with masks, they are immune to all gases save vesicants. For this reason, such gas attacks would seem to have a chance for use in the present conflict. But neither of the belligerents will care to initiate the weapon as long as the possibility of reprisal exists.

If and when Germany can severely incapacitate Britain's chemical industry, or *vice versa,* a mustard gas attack would be "safe" for the winning side. The fear of a retaliation would then be absent. That the chemical and not the aircraft industry can be put out of action is because Britain's chemical industry is concentrated in the Midlands, while Germany's is mainly in the Rhine valley. Bunched targets make for easier bombing.

The manner of dispersing the gas must then be solved. In the last war, gases were released with shell and grenade fire and through cylinders encased in dugouts. To repeat this procedure, Britain must invade the continent or Germany go over to England.

The release of gas through airplanes was tried by the Italians in their conquest of Ethiopia, against unprotected combatants. The same lack of wind and general climate conditions which the Italians found does not prevail in the European theater of war. New methods of airplane dispersal must therefore be found. Also air mastery must be gained. And with the latter, the necessity of a vesicant attack almost vanishes.

Should either side have control of the air, with the other refusing to surrender, vesicant attacks still seem unlikely. Britain will want to rely more upon arousing the conquered peoples of Europe. Besides alienating world opinion, gas attacks will not serve this end. Germany, too, will want to avoid the indignation of non-belligerents and not give her subjected nations more cause for discomfort. If a victory can be had through continued bombing, through invasion, through propaganda, through a war of nerves, why should gas be employed?

BOOKS ON SCIENCE FOR LAYMEN

TIME AND MYSTERIES[1]

THIS second volume of the lectures given at New York University on the James Arthur Foundation maintains the high standard of its predecessor. The deed of gift allows a wide range of subject, which is well illustrated by the four contributions here assembled. Professor D. W. Hering, of New York University, discussing "The Time Concept and Time Sense among Cultured and Uncultured Peoples," draws upon his own memories of almost eighty years before, when the time of an evening meeting was posted at the village store as "early candlelight," speaks of the gradual development of an accurate sense of time as life became more complex, and takes advantage of the knowledge gained as curator of the James Arthur Collection of clocks and watches to tell the tale of the misfortunes which beset Galileo's early attempt to construct a pendulum clock.

Speaking to the title, "What is Time"? W. F. G. Swann makes bold to takes his hearers into the "Torture chamber" (his own phrase) of relativistic theory. Under his guidance, the visit has no terrors. Those who know him will anticipate, and all will welcome, the accuracy and lucidity of his exposition, and the epigrammatic wit which we have learned to expect from him is there in full measure. For example, after explaining why *each* of two observers in relative motion will conclude that the other's clocks run slower than his own, he sums up: "In fact, my address is longer to everybody else than it is to you. Think how fortunate you are."

The third lecturer, John Dewey, enters quite a different field with "Time and Individuality"—which makes his contribution of exceptional interest to one who, like the reviewer, has habitually to deal with the physical aspects of time. "Temporal seriality" says he "is of the very essence, then, of the human individual. It is impossible for a biographer in writing, say the story of the first thirty years of the life of Lincoln, not to bear in mind his later career."

The much-debated question whether some degree of similar seriality—some change and development with time—is to be found in the elements of physical nature, is clearly put. Without dogmatizing on its answer, Professor Dewey says: "Since it is a *problem* I am presenting, I shall assume that genuine transformations occur, and consider its implications." With the philosophical conclusions concerning contingency we may not all agree. But he has the great advantage of dealing with matters which bear on life and action. From his conclusion we quote: "It is easy in the present state of the world to deny all value whatever to the idea of progress, since so much of the human world seems bent on demonstrating the truth of the old theological doctrine of the fall of man. But the real conclusion is that, while progress is not inevitable, it is up to men as individuals to bring it about." These words were spoken three years ago. They have added force to-day.

Arthur Compton, speaking of "Time and the Growth of Physics," returns us to the realm of abstract thought, and hence inevitably to the consideration of relativity—which, in one aspect or another, none of his three predecessors had been able to escape—but returns to psychology, nay, to the higher criticism, before the end. "We frequently comment that rapid transportation has greatly shortened distance. It would be equally true to say that our days have been lengthened because so much more hap-

[1] *Time and Its Mysteries.* Series II. $2.00. 1940. New York University Press.

pens to us. Did not the Israelites declare that Joshua had stopped the Sun and Moon as they were chasing the Philistines? So much happened that day that only thus could its increased length be described."

It seems to be as hard to keep psychology out of a discussion of time as to exclude relativity. It is partly, though not wholly, because they were not kept out, that this excellent little book offers so much in the way of enjoyment, as well as illumination, to its readers.

HENRY N. RUSSELL

A BIOLOGIST LOOKS AT SOCIETY[1]

WHAT constitutes adventure? For one it may be exploring new countries and discovering new races and previously unknown cultures, but for Dr. Haldane adventure lies in his scientific work, for there he can learn new truths and see how they can be applied to human welfare. He is not one of those scientists who, as he says, "contrive to live in little worlds of their own, cut off from the big world. Or rather who contrive to think that they do. . . . I have never held it, but since I began to study the application of scientific method to the development of societies, I have certainly felt more justified in my attempts to popularize all kinds of science."

The first of these essays, for this is a collection of essays which have been published in magazines from 1932 to 1939, treat of such unsolved problems of science and everyday living as the weather, the composition of the earth and the sun, how health may be bettered, as well as the problem of life itself and its inevitable partner, death. He next shows how science has approached problems in the past, choosing as his illustration the problem of respiration under high pressures, a problem with which he has worked directly.

However, by far the most interesting parts of the book are those chapters in which he tried to apply scientific principles to society and to governments. He discusses present-day conditions, those in 1939, using England as his example. He is very frank in his criticisms and points out weaknesses and dangers which to-day are very evident. It is easy to see why many would object to his ideas. However, his criticisms are constructive, for he tells what he thinks must be done to correct conditions if the world of the future is to be organized along really scientific lines, lines which are at the same time truly humanitarian.

We may not all agree with his conclusions, but his ideas are stimulating and, even more important than the ideas themselves, is the method by which he arrived at them. I am sure that we will all agree with him in the statement that "we need more science, not less, and science applied not only to certain branches of production, destruction, and medicine, but to human life as a whole." All in all the book is stimulating and well worth reading.

D. B. YOUNG

[1] *Adventures of a Biologist.* J. S. B. Haldane. vii + 281 pp. $3.50. 1940. Harper and Brothers.

FIGHTING THE FUNGI THAT ATTACK MAN'S FOOD SUPPLY[1]

GIVEN an author who has written two successful novels and whose vocation is the chemical control of fungi, one might expect a popular book on fungous diseases of plants that would be readable and interesting to the layman as well as to those engaged in repelling the attacks of fungi on plants. In this book, E. C. Large fully lives up to this expectation. He has written an interesting and spicy account of the history of phytopathology by carefully selecting the phases of its development that have an appeal to the general reader without, however, sacrificing scientific accuracy and complete-

[1] *The Advance of the Fungi.* E. C. Large. Illustrated. 488 pp. $4.00. 1940. Henry Holt and Company.

ness. He has also discussed fully some of the most sensationally destructive diseases. It probably will be news to most laymen that the potato-blight fungus was the chief cause of the great famine in Ireland near the middle of the 19th century. As the author states, "By destroying the stable food supply of a human society, already very sick from economic causes, it brought about more of death and suffering than any other disaster since the Napoleonic wars." As suggested by this quotation, the author has stressed the effect of plant diseases on human affairs and what man has done to overcome them.

Although the author is an Englishman, his point of view is world-wide. His discussions include some of the principal diseases affecting American agriculture, and the work of American investigators is highly praised. One chapter is even headed "The Lead of the U. S. A." In addition to fungous diseases in the narrow sense, there are also interesting discussions of bacterial and virus diseases. The author also gives the reader some idea of the methods used in discovering the causes of plant diseases and the establishment of preventive measures. The steps leading to discovery of Bordeaux mixture and its development by Millardet are told in a way that should appeal to any one interested in how epoch-making discoveries come about. Equally interesting are the chapters on new sprays for preventing fungus infection and efforts to obtain resistant or immune plants.

Most American investigators would probably consider the author overly optimistic regarding copper substitutes for Bordeaux mixture. Although there are good illustrations of fungi and diagrams showing their life cycles, one misses the excellent half-tones of the diseased plants or plant parts that are found in such British books as Rolfes's "Romance of the Fungus World" and Wormald's "Diseases of Fruits and Hops." Surely a reproduction from a photograph would give the reader a much better idea of a scabby apple than the drawing shown as Fig. 48. An American author would probably have included the devastating chestnut blight that has eliminated the chestnut as a forest tree in the United States, and the brown rot disease of stone fruits that annually causes heavy losses in this country, but these are omissions of slight importance. They would only be additions to the other thrilling tales of man's fight to save his timber and his food supply.

This sprightly and beautifully written book on the major accomplishments of the science of phytopathology should not only be intensely interesting to the layman, especially the agriculturist and the historian, but it should give the professional phytopathologist a pride in his science and its founders and should be a source of inspiration, particularly to the younger workers in this field.

John W. Roberts

DEALING WITH HYPNOSIS[1]

Here is another book dealing with the more superficial aspects of hypnosis. This differs from the others only in its magic repetition of the phrase, "autonomic nervous system," by which the author would explain hypnosis and also "hysteria . . . . psychoanalysis, Christian Science, and other forms of faith-healing." Such an approach is particularly unfortunate to-day when hypnosis is being revived for important new research on the dynamics of personality and there is a real need for a comprehensive survey of the field.

Leslie H. Farber

[1] *Scientific Hypnotism.* R. B. Winn. 168 pp. $1.75. 1939. Christopher Publishing House.

Kerseboom p. From an Original in the possession of Dr Mead ex. G. Vertue Sculp. 173

THE PROGRESS OF SCIENCE

ROBERT BOYLE, 1627–1691

Robert Boyle died two hundred and fifty years ago; yet his name is familiar to every student of elementary physics because he discovered a famous law that bears his name. He found by experiments that the pressure of a gas upon the walls of a retaining vessel varies inversely with its volume, provided its temperature is kept constant. This law and that of Charles, with the slight corrections they require for large changes in pressures and temperatures, were essential steps toward the vast scientific generalizations comprised in the molecular structure of matter, the kinetic theory of gases and the kinetic nature of heat energy.

Boyle was born when rapidly expanding science was having profound effects upon all the realms of thought. Magellan had sailed around the earth (1518–1521), Copernicus had published his heliocentric theory of the solar system (1543), Tycho Brahe (1546–1604) with scrupulous care had observed and recorded the motions of the planets, Kepler (1571–1630) had proved that the planets revolve about the sun in elliptical orbits, and Francis Bacon (1560–1626) had published his great discussion of scientific methodology.

When Boyle was born young men had been studying at Oxford and Cambridge for more than three hundred years, printing with movable type had been practiced for more than a century, Shakespeare (1564–1616) had written his immortal plays, the Gregorian calendar had been established (1582) and the King James translation of the Bible had been published (1611). Science was on the march, but it did not march alone. The human mind was moving in many columns.

Robert Boyle, the fourteenth child of the great Earl of Cork, was born at Lismore Castle, in Ireland, on January 25, 1627. He was a precocious child, learning to speak French and Latin in his early years and entering Eton at eight. At eleven he was traveling with a French tutor on the Continent, and at fourteen he was studying under Galileo at Florence. At seventeen he went to London and there dedicated his life to science. He soon became a member of the "Invisible College," an organization of young men who were devoting themselves to "the new philosophy." In 1663 the Invisible College evolved into the Royal Society of London for Improving Natural Knowledge, in the charter of which King Charles II named Boyle a member of its Council. In 1680 Boyle was elected president of the Royal Society, but he declined to accept the honor because of his scruples about taking an oath. A little over a century later the Invisible College and its evolution into the Royal Society of London was interestingly paralleled by the informal society Benjamin Franklin organized in Philadelphia in 1743, and which in 1780 became the "American Philosophical Society Held at Philadelphia for Promoting Useful Knowledge," to give it its complete original name.

Boyle published his famous law on gases in 1660. He was, however, more interested in chemistry than in physics, and in 1661 published a book entitled "The Sceptical Chemist." Hoping to be able to transmute metals, he was instrumental, in 1689, in getting the repeal of a statute of Henry IV against multiplying gold and silver. To-day twenty thousand tons of gold ingots lie buried in Kentucky, unused and perhaps never to be used except for industrial purposes. In the field of physics, Boyle investigated the role of the air in propagation of sound, the expansive force of freezing

water, the specific gravities and refractive indices of several important substances; in the field of chemistry he investigated the chemical nature of combustion and respiration. When he took up problems in physiology he was hampered by the "tenderness of his nature" which kept him from making dissections.

There was another side to this talented and versatile Irishman—he was greatly interested in theology, so much that he would have been made provost of Eton in 1665 if he had taken orders. He learned Hebrew, Greek and Syriac in order that he might pursue his scriptural studies in the original languages. In spite of this he spent large sums for translations. In his will be founded the Boyle Lectures, which were established for the purpose of proving the truth of the Christian religion against "notorious infidels, *viz.*, atheists, theists, pagans, Jews, and Mohamedans," with the proviso that controversies among Christians should not be mentioned.

F. R. M.

RESEARCH CONFERENCES IN CHEMISTRY AT GIBSON ISLAND

In each of the past four summers Dr. Neil E. Gordon, secretary of the section on chemistry of the American Association for the Advancement of Science, has organized and conducted special research conferences on chemistry at Gibson Island, Maryland, under the auspices of the Association. These conferences have increased so rapidly in size and importance that the association has recently purchased a fine property on Gibson Island to give them a permanent home. This purchase was made possible by contributions from industrial laboratories who had sent one or more of their staff members to the conference.

For many years biologists have had laboratories for summer use at various

GROUP OF CHEMISTS IN FRONT OF THE CONFERENCE HOUSE AT GIBSON ISLAND WHO ATTENDED THE CORROSION CONFERENCE IN AUGUST.

favorable locations. Research workers from many institutions have gathered at them, often year after year, to avail themselves of the exceptional opportunities offered and especially to confer with their fellow scientists. The rapid progress made in the biological sciences undoubtedly owes much to these summer laboratories. The geologists conduct field excursions and the astronomers go long distances, perhaps half way around the earth, to observe eclipses. In all these cases the scientists go to places where the material exists in which they are interested. The chemists, in the Gibson Island conferences, leave their chemicals and their laboratories and go to a place having many attractions during the summer—golf, tennis, bathing, yachting and prevailing fresh breezes from the Chesapeake Bay.

PAVILION ON THE BEACH

Chemists, however, are no more given to levity than their fellow scientists in other fields, as the routine of their life at Gibson Island will illustrate. Each of their conferences is devoted to a single well-defined subject and continues for five days, Monday to Friday, inclusive. For example, the eight conferences held this past summer were devoted to such subjects as Catalysis, Vitamins and Photosynthesis. All the scientific programs are held on a large screened veranda of the property which has recently been purchased by the association. Each session begins at 10 o'clock in the morning and continues until about 12:30. The program, which has been planned by a committee of experts in the field, consists of only one or two papers, leaving the remaining time for discussion. The meeting adjourns for luncheon at the Gibson Island Club. There are no formal scientific programs in the afternoon. The evening programs, which are similar to the morning program, continue until —well, until they stop, perhaps at midnight.

DR. NEIL E. GORDON
UNDER WHOSE DIRECTION THE CONFERENCES ARE CONDUCTED, STANDING IN FRONT OF ST. CHRISTOPHER'S BY THE SEA.

As necessary as laboratories and equip-

ment are in most sciences, it is easy to overestimate them relative to ideas—of course, ideas that are in harmony with experience. It is in the realm of ideas that the Gibson Island conferences make their great contribution. No science owes more to ideas, mental concepts, than does chemistry, whose very elements are all wholly beyond the direct reach of the senses. Among the most interesting and remarkable achievements of the human mind is that of inferring the structures of organic molecules. And interestingly, their beauty is fully matched by their usefulness in producing desirable chemical products.

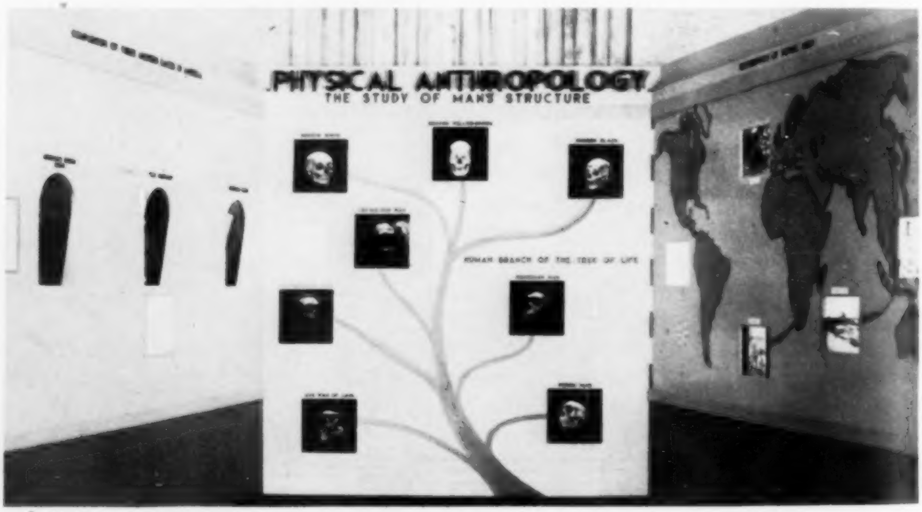
Ideas and reports of experiments are the specimens exhibited at Dr. Gordon's conferences. The ideas are not those that have long been crystallized but those that are taking form, conjectures thrown out freely among friends for criticism. Naturally sparks of inspiration are struck when sharp minds meet sharp minds. Sometimes they suddenly throw light on a whole field, as a flash of lightning at night illuminates for the chemists on the veranda the golf course below and the bay stretching away in the distance.

The property bought by the association consists of a large house on a lot of 3.6 acres in area, situated on a tree-covered hill, the highest on the island. It provides accommodations for between twenty and thirty scientists, the remainder of the limit of sixty for each conference being housed at the club. The island, between three and four square miles in area, is situated in Chesapeake Bay about twenty miles south of Baltimore. It is privately owned and admission to it over a causeway is only by card issued by the club.

F. R. MOULTON

PHYSICAL ANTHROPOLOGY IN THE NEW INDEX EXHIBIT OF THE SMITHSONIAN INSTITUTION

IN the southeast quarter of the Main Hall of the Smithsonian Building, a semi-circular alcove and a three-sided alcove have been arranged to portray



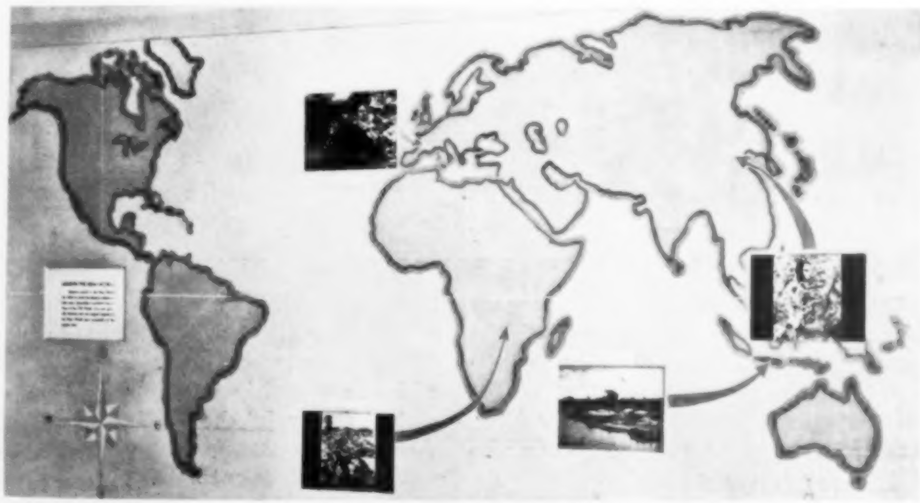
PHYSICAL ANTHROPOLOGY ALCOVE OF THE SMITHSONIAN INDEX EXHIBIT

THE EIGHT RACES OF MANKIND ARE REPRESENTED IN THE CENTRAL PANEL BY FIVE FOSSIL SKULL CASTS AND THREE ORIGINALS.

COMPARISON OF THE THREE MODERN RACES IN THE UNITED STATES
APPEARS IN THE LEFT-HAND PANEL WHICH CONTAINS PLASTER CAST BUSTS FROM THE MOST TYPICAL INDIVIDUALS OF THE INDIAN, "OLD AMERICAN" AND NEGRO RACES.

graphically the institution's activities in the field of anthropology. Adjoining the quadrant illustrating the History Section is the alcove devoted to that branch of anthropology dealing with the study of man himself, namely Physical Anthropology. This branch is concerned with the origin of man, his development from fossil to modern forms, racial classification and differentiation, race mixture and the inheritance of bodily characters and his present and future evolutionary changes. Only two phases of this subject are displayed by objects and charts of general interest.

On the central panel a hypothetical diagrammatic branch of a biological "tree" has been painted to show the theoretical relationship in the development of man from fossil to modern types. In the eight recessed boxes are displayed accurate casts of five types of early man, and three original skulls showing the main variants in modern human races. Beginning with the oldest form there are shown the *Pithecanthropus erectus* or the Java ape man, the *Sinanthropus* or Peking man, the Rhodesian man of South Africa, the Neanderthal man of western Europe, the Cro-Magnon man of France,



LOCALITIES OF DISCOVERIES OF REMAINS OF FOSSIL MAN
ARE SHOWN IN PHOTOGRAPHS AND MAPS IN THE RIGHT-HAND PANEL OF THE PHYSICAL ANTHROPOLOGY EXHIBIT.

and a modern White American, a Yellow-brown (Mongol) and a Black (Negro).

On the panel to the right is a flat projection in color of the various continents, with arrows pointing to the locations from which four of the aforementioned fossil forms were recovered. The slightly recessed transparencies on this panel illustrate excavations at Chaukoutien near Peking, China, which yielded the *Sinanthropus;* the site of Bengawan River, near Trinil, Java, which gave the *Pithecanthropus;* the Broken Hill mine of Northern Rhodesia, Africa, where the "Rhodesian" skull was found; and the cave of La Chapelle-aux-Saints, France, where one of the already numerous remains of Neanderthal man was recovered.

The label between the continents of North and South America indicates that extensive search in the New World has failed to reveal physical remains of early man comparable in primitive form to those of the Old World. It is now generally believed that the original migrants to the New World were essentially of the modern form.

The studies in physical anthropology extend not only to the skeletal remains of man, but where possible also to the living. The panel to the left illustrates a comparison of the three main modern races in America. In the recessed niches are shown faithful plaster busts made from living individuals of an American Indian (Sioux), an "Old American" White and an American Negro.

In the study of the living, as well as that of the skull and other skeletal parts of the human body, numerous measurements are usually made. These measurements and the landmarks used (*i.e.*, the points at which the measurements are taken) have been standardized to a large extent by international agreement, so that they may be taken with similar instruments and in the same way the world over, and thus assure data that can safely be used for human comparisons and prove of scientific value. The measurements supplement the visual and other instrumental observations; the ultimate object of all such research is to learn thoroughly everything that relates to the physical man and, with this knowledge as a basis, assist in his future progress.

The Division of Physical Anthropology in the U. S. National Museum has a classified skeletal collection numbering 37,000 specimens, which has long been used by anthropologists, medical men and dentists for their studies. It excels in well-documented series of American Indian and Eskimo material, and includes a rich and highly valuable human, ape and other animal brain collection.

FRANK M. SETZLER

X-RAYING A MUMMY AT THE FIELD MUSEUM OF NATURAL HISTORY

HARWA, a Twenty-second Dynasty Egyptian mummy, was keeper of the storage houses on the estate of one of the temples of Amon, the chief God of the Empire, some 2,800 years ago. Now, Harwa is the only adult-sized person who is publicly fluoroscoped every day. Loaned by the Field Museum of Natural History for exhibition at the New York World's Fair, he was seen by millions of people. The physical set-up of the exhibit, in which the mummy is shown, was a gift from the General Electric X-ray Corporation, whose engineers and technicians assisted in installing it in a special chamber in the Hall of Egyptian Archeology.

When visitors enter this chamber they see Harwa in his external mummy wrappings illuminated by amber spot lights. The lights fade out and the fluoroscopic screen slides into place. After a short

THE MUMMY IN THE X-RAY CHAMBER
BEFORE THE FLUOROSCOPIC SCREEN MOVES IN FRONT OF THE FIGURE.

X-RAY IMAGE OF THE SKELETON
OF THE MUMMY AS IT APPEARS ON THE FLUOROSCOPIC SCREEN.

interval of darkness to accommodate the eyes, the x-ray is energized and projects the image of Harwa's skeleton upon the screen. The cycle is 40 seconds and is repeated automatically throughout the day. There is also selective control for use when visitors are few in number—then they may themselves operate the exhibit by pushing a button.

The machine used is a therapy apparatus with a Coolidge tube unit on a fixed mount. As the anode angle of this tube permits field coverage of a diameter equal to the distance, the "treatment cone," a pyramidal lead-lined box, is 160 cm long—Harwa was shorter in stature than the average Egyptian. The fluoroscopic screen is mounted behind lead glass for the protection of visitors.

A series of stereoscopic radiographs made of Harwa through the courtesy of the University of Chicago's medical department, and their study by a highly qualified roentgenologist, fail to reveal the cause of death. The twelfth left rib is missing, opening the question as to whether it may have been removed by the embalmer, or was congenitally absent.

There is no evidence of osteoarthritis. This is unusual among adult Egyptians, as their daily life was so intimately bound up with the River Nile. Irrigation, fishing and boating all called for frequent contact with the water, and contrary to the general impression the climate of Egypt is often disagreeably cold. There is a possible indication that Harwa may have had an alveolar abscess about the anterior root of the lower right first molar. The average Egyptian had excellent teeth, dental trouble being largely confined to the upper classes with their pampered diets. The examination confirms the conclusions of archeologists that the mummy is that of a male, and that Harwa was between 25 and 40 years of age at the time of death.

The study by a roentgenologist, and the exhibit of Harwa at Field Museum, both using the most modern of medical aids, make a link with the beginnings of medical science. Doctors were a recognized part of the ancient civilizations of the Near East. By 2000 B.C. surgical practices were covered by law. A section of the Code of Hammurabi, King of Babylon, states: "If a physician make a deep incision upon a man (perform a major operation) with his bronze lancet and save the man's life; or if he operate on the eye socket of a man and save that man's eye, he shall receive ten shekels of silver." However, the law continues, if the operation were unsuccessful and the patient should die or lose his eye, the physician's hand would be cut off. Rates varied with the social scale, just as some physicians to-day base their charge on the patient's ability to pay. The common man was charged only five shekels for a ten-shekel treatment, and the slave but two shekels.

From Egypt, at about the same period, come surgical texts dealing with examination, diagnosis and treatment. Splints were employed for broken bones, and in severe cases the patient's body was immobilized in the correct position by casts of mud. The custom of mummification provided aids for the skill of the surgeon. The embalmers' fine linen wrappings made excellent roller bandages, and wounds were drawn together with adhesive tape. The use of stitching to close large incisions was used on the dead, and may have been employed on the living. Later, in the third century B.C., a great medical school developed in Alexandria. From this Egyptian school came two great Greek physicians: Herophilos, father of anatomy, and Erasistratos, father of physiology.

RICHARD A. MARTIN

STATIC ELECTRICITY AND AUTOMOBILES

STATIC electricity means little less to the layman than a nuisance in his radio reception, or a plaything for him to draw sparks from door-knobs or to display his "magic powers" by lighting a gas burner from his knuckles. Since technical literature, beyond the covers of the text-book, is practically destitute of information on the generation and behavior of static electricity, relatively few are aware of the fact that each year it takes a considerable toll of life and an economic loss totaling many millions of dollars results annually from its fires and explosions.

Static Electricity in Industry: In industry, electrostatic potentials may be encountered as high as 75,000 volts. The more common sources of such generation are rapidly running belts driving machinery, belt conveyors employed in granaries, coal handling or package conveyance, compressed gases escaping from jets or nozzles, paper running over rolls during its manufacture or printing, fluids, such as petroleum distillates, flowing rapidly through pipes or hose lines into terminal tanks, or rubber-tired vehicles in running along the highways. Since the electrification of rubber-tired vehicles has become particularly hazardous in the haulage of inflammable substances such as volatile petroleum distillates and explosives, the author undertook an experimental study of static electricity to determine how it was generated and stored on a vehicle, how it subsequently behaved and how its control and harmless discharge might be effectuated.

Electrification by "Contact Difference of Potential": Experiment has shown that when two unlike substances are pressed firmly together, such as rubber tires on the roadway, electrons escape from the molecules of the concrete or asphalt and pass into the rubber treads of the tires. These electrons are known to be the smallest indivisible particles of negative electricity, and they are normally constrained to their orbits or shells within the atoms by the intra-atomic electrical forces which exist in the neutral atom between them and the equal number of positive particles which are compacted into the nucleus.

So, when these unlike substances, the tires and the roadway, are in contact with each other, an unbalance of the intra-atomic forces occurs at their boundary surfaces which thereby permits a relatively small proportion of the billions of these electrons to pass from the roadway into the tire treads. In this way a difference of potential is established between the two contacting substances—the negatively charged tires and the positively charged roadway. Its value, however, is small, being of the order of a fraction of a volt. This principle by which voltage is produced is properly known as "contact difference of potential," a concept none too well understood as yet, and commonly, though erroneously, referred to as "frictional electricity."

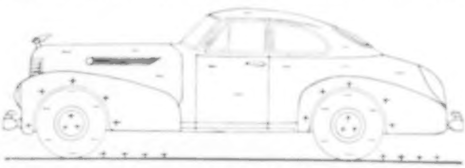


FIG. 1. DISTRIBUTION OF ELECTRIC CHARGES
ON AN AUTOMOBILE BROUGHT ABOUT BY THE PROCESS OF ELECTRIC CONDUCTION.

In insulating materials, as these are, the electrons are more or less rigorously constrained from flowing readily from one place to another. In conductors, on the other hand, such as metals, electrons migrate freely from place to place, a property from which they gain their name of "free electrons."

The two charged surfaces, the tire treads and the roadway, separated as

FIG. 2. A PASSENGER CAR BEING TESTED FOR ELECTROSTATIC VOLTAGE

they are by about 1/100,000,000th of an inch, or the approximate diameter of a molecule, constitute an electrical condenser. The capacity of this condenser to store electrical charges increases directly with the area of the charged surfaces and with the voltage between them, and inversely with the distance separating them. If the surfaces, having been charged, are now appreciably separated, the voltage between them is found to increase as their separating distance increases. This is the reason why such a small contact potential difference as a fraction of a volt will multiply into many thousands of volts when the surfaces are separated by, say, several inches.

Electrifying Rubber-tired Vehicles: As each unit of area of the electrified tire treads separates from its ultramicroscopic closeness with the charged pavement, as the wheels roll along the highway, the voltage between the two increases greatly. The average voltage between the tire tread and ground, however, can only increase when additional charges are imparted to the treads, and, as will be seen from the results of test, this condition depends essentially on the speed of the vehicle, on the degree of tire inflation, on the value of the tire loads and on the grades of the roadway.

The process by which the body of the vehicle is ordinarily electrified from the charged tires is called "electric induction." The high electrification possessed by the tire treads causes the free electrons in the closely adjacent metal parts, the fenders and wheels, to be repelled to the more remote areas of the car body as the so-called "free charge." An equal amount of positive charge is then left behind on the fenders and wheels as a so-called "bound charge." It is held there, separated from the negative charge on the tires, by the ultra-high resistivity of the side walls of the tires or of the intervening air. This normal distribution of the electric charges on a rubber-tired vehicle by the process of electric induction is shown in Fig. 1.

Testing on the Otis Proving Stand: The electrification of car bodies was found to be affected by humidity, air and tire temperatures, tire inflation and loading, condition of the tires and roadway, speed of travel and the grades of the roadway. Since these variable factors could not be individually controlled during tests on the highways, an Otis Proving Stand, a high-speed chassis dynamo-

meter, was eventually employed, through the auspices of the Brooklyn Edison Company and the Gulf Oil Company, in obtaining the final quantitative results. An inspection of Fig. 2 shows a vehicle operating on the dynamometer during one of the tests. The drive wheels of the vehicle run on steel drums which may be variously loaded to simulate driving conditions on level roadways or on upgrades. A car may operate on the test stand over a speed range to 70 m.p.h. The voltage, generated between the car body and the "grounded" drums, was measured by means of an electrostatic voltmeter which was provided with four scales, the highest reading to 30,000 volts.

The Characteristics of the Generated Voltage: Under the conditions of no load on the car, such as running along a level roadway, the voltage of the car to ground was found to vary with the speed—linearly at the lower speeds and approaching a constant voltage at high speeds. Also the voltage was found to depend upon the degree of tire inflation, being higher for the higher pressures. The variation of voltage with speed is shown in Fig. 3 for three values of tire inflation for a passenger car and similarly for a 5-ton truck. From these and other tests it is estimated that, under favorable conditions, the voltage generated by heavy, high-speed trucks or buses will range between 30,000 and 40,000 volts.

Additional tests were made to determine the influence upon the generated voltage of a vehicle under load, such as operating on up grades of increasing steepness. These loads are specified by the driving force, or "tractive effort," in pounds push at the treads of the rear driving wheels. These tests showed that the voltage increased linearly with the tractive effort, as may be seen in Fig. 4. The steepness of these curves is considerably greater for the truck than for the passenger car, a condition which conforms with the principle of "contact difference of potential." Since the push on the treads of the truck tires is greater than for the passenger car, because of the much greater weight of the former, the surfaces of the tire treads must tend to enmesh with the roadway in more in-

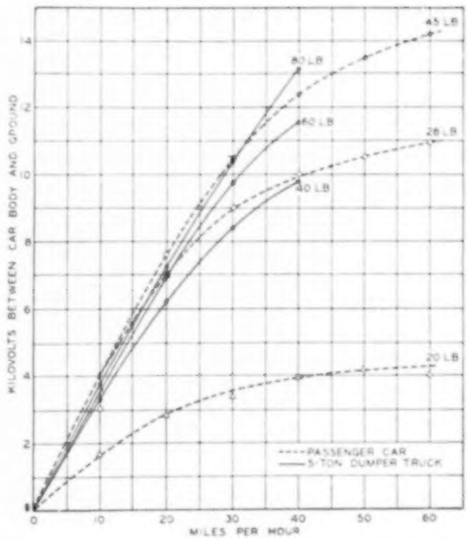


FIG. 3. EFFECT OF SPEED ON VOLTAGE FOR THREE VALUES OF TIRE INFLATION IN THE CASE OF A PASSENGER CAR AND A TRUCK.

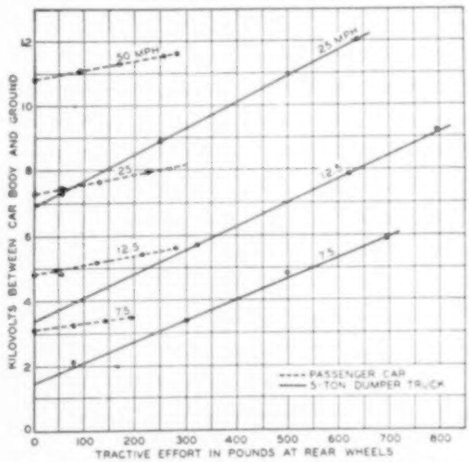


FIG. 4. VARIATION OF VOLTAGE WITH LOAD

AT FOUR SPEEDS FOR A PASSENGER CAR AND THREE SPEEDS FOR A FIVE-TON TRUCK.

timate contact. Consequently, more electrons are appropriated from the road surface by the tires, and thereby a higher voltage per unit of tractive effort results.

Ineffectual "Grounding" Practises: The "drag chain," as commonly seen dangling from the rear of gasoline tank trucks, has for its alleged purpose the conduction to ground of the "free" negative charges on the body of the vehicle, so as to eliminate electric sparks and thereby remove the attendant fire and explosion hazards. On a number of occasions during tests, an electrified car body showed no appreciable leakage of its charge over a period of a half hour or more, in all of which cases skid chains had been draped from both front and rear bumpers to the roadway.

Since the dry roadway presents a surface of most excellent insulating properties, obviously the charges are effectively impounded on the car body and, hence, they can not discharge to ground. These and other tests have clearly demonstrated the futility of drag chains as a means of grounding. Likewise the many other "gadgets" employed to accomplish this purpose of discharging the vehicle to ground, through the intervening roadway, including conductive rubber tires, are equally ineffective on highways for which the materials of construction and the surfaces possess ultra-high electrical resistivities.

Trends toward a solution: An effective solution of the problem of discharging electrical rubber-tired vehicles suggests itself from a study of the various basic factors; but, under present methods of highway construction, this solution does not have an immediate or simple application.

Assume that the surface of the highway could, in some way, be made conductive, then, by using conductive rubber tires, which are now available on the market, the electric charges, if generated by the tires and stored on the car body during its operation, would flow away to ground as soon as the vehicle came to a stop. As a substitute method, but one of much less efficacy, the expansion joints as now commonly used, every few feet apart, on concrete highways, could be made of conductive composition and thoroughly grounded. By this means, the vehicle would discharge to a fairly low potential at the last ground joint encountered before its final stop. These discharge joints would likewise be required on asphalt and macadam roadways.

If the highway engineer could ingeniously formulate a conductive composition with which to face the roadway surfaces, as effectively as the research engineer has developed conductive rubber tires by "loading" the rubber with conductive carbon black, fire and explosion hazards resulting from static electricity on rubber-tired vehicles would no longer be a problem. Some study into these proposed methods might yield encouraging results.

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